Mapping wild fires in Prespa reedbeds: use of BAIS2 Index and drone images

Short-communication technical report within the framework of

LIFE Project “Prespa Waterbirds”

LIFE15 NAT/GR/000936

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Summary

Remote sensing techniques can provide tools for mapping hazards in natural ecosystems, including wildfire events, targeting accurate mapping of distribution as well as post-event monitoring and recovery. Since 2019, whole lakeshore mapping of wildfire events and distribution in Lesser Prespa is implemented targeting solely the effects on reedbeds within the LIFE project Prespa Waterbirds. Based on previous work done in the area, fieldwork data coupled with sentinel-2 satellite images and remote sensing methodologies were used as a workflow pipeline in order to improve the delineation of wildfires in Prespa reedbeds. The implementation of the method used in 2019 (Burn Area Index for Sentinel-2 BAIS2) gave poor results in 2020. Therefore, a derivative of BAIS2, namely the deltaBAIS2, was created and is used since 2020. This derivative index is calculated as the difference before and after fire events of the value for each pixel of the BAIS2 index.

For 2021, at the same time as this analysis of satellite images, the use of oblique aerial images from drone missions to map burnt areas was tested, with a georeferencement tool from ArcMap.

Both analysis (dBAIS2 and drone images) gave quite equivalent results and could be complementary. The satellite method is used to identify fire zones and map them while the drone method can be used to refine the delineation of burned areas.

A step-by-step methodological framework of drone photo analysis is also presented, to guide post-LIFE mapping of wildfire events.

Key word: Remote sensing, reedbeds, wildfires, Sentinel-2, mapping, drone, georeferencing and projective transformation

1. Introduction

Rapid post-fire mapping is fundamental to support fire management, account for environmental impact, define planning strategies and for the monitoring of vegetation recovery (Sakellarakis et al., 2018).

Burn Area Index (BAI) or Normalized Burn Ratio (NBR) indices are commonly used for efficiently mapping areas damaged by wildfires in natural ecosystems (Key & Benson 1999, Chuvieco & al., 2002). Although both indices (BAI & NBR) are widely used for mapping fire extension and effects in different type of ecosystems, they were originally designed for mapping fires in forests (Key and Benson 1999). Epting et al. (2005) and Salvia et al. (2012) have demonstrated that NBR index is not performing well when used for mapping wildfire extent in unforested or herbaceous wetland vegetation communities. The NBR index was tested to map the distribution of fire events that took place in the reedbeds of Prespa but, unsurprisingly, provided unsatisfactory results.

An alternative index for post-fire burned area detection, namely the Burn Area Index for Sentinel-2 (BAIS2), was developed and designed by Filipponi (2018) taking advantage of the Sentinel-2 new Multispectral Instrument (MSI) spectral characteristics while adopting a spectral combination of bands that have been demonstrated to be suitable. The new Multispectral Instrument (MSI) on-board of Sentinel-2 satellite carries more spectral information recorded in the Red-edge spectral region which is one of the best spectral range for radiance-based descriptors of chlorophyll content.

The index BAIS2, use a band ratio in the red-edge spectral domain, which aims to describe vegetation properties, combined with a band ratio to detect the radiometric response of the SWIR (Short-Wavelength InfraRed) spectral domain, largely recognized to be efficient in the determination of burned areas (Filipponi 2018).

2.Methods

2.1 Reminder of the methodology.

The BAIS2 index (Filipponi, 2018) was computed according to the following formula:

$$BAIS2 = \left(1 - \sqrt{\frac{B06 * B07 * B8A}{B4}}\right) * \left(\frac{B12 - B8A}{\sqrt{B12 + B8A}} + 1\right)$$

The resulted raster files were combined with a raster mask of reedbed distribution (based on Vrahnakis et al., 2011 and Sakellarakis et al., 2018).

Since 2020, we have studied the evolution of BAIS2 values <u>before</u> and <u>after</u> fire events. BAIS2 values of unburned pixels should not vary in time as much as burned pixels values that are expected to differ importantly before and after a fire event. We calculated the difference between these two periods according to this formula:

$$dBAIS2 = BAIS2\ (post\text{-}fire) – BAIS2\ (pre\text{-}fire)$$

The first fire event was identified between February 5th-12th and the last wildfire occurred on May 6th (Table 1). To cover this period seven Sentinel-2 scenes were used between January 28th and May 11th (Table 1).

Table 1. Dates of Sentinel-2 satellite images (scenes) and fires events during 2021.

Available Sentinel-2 scenes (dates)	Fire events (dates)
28/01/2021	
	Pyli – unknown date between 05/02 to 12/02/2021
04/03/2021	
	Pyli – unknown date between 7/03 to 14/03/2021
27/03/2021	
	Pyli – unknown date between 29/03 to 03/04/2021
	Pump station - unknown date between 29/03 to 03/04/2021
	Karyes - 28/03/2021
06/04/2021	
	Pyli – unknown date
26/04/2021	
28/04/2021	
	Karyes unknown date close to 01/05/2021
	Slatina Laimou – Slatina Plateos 06/05/2021
11/05/2021	

The fire events were pre-spotted in two ways:

- Society for the Protection of Prespa managed to observe and inventory a number of them,
- preview of S2 satellite images on EO browser enabled missing events to be detected. (https://apps.sentinel-hub.com/eo-browser/).

2.2. Histogram distribution of delta BAIS2 values in 2021.

BAIS2 pixel values do not vary much over time on the unburned areas. As a result, DeltaBAIS2 of unburned areas form a cluster of values around zero [Figure 1 (green ellipse)]. In contrast, burned pixels exhibit larger variations of BAIS2 before and after a fire took place resulting in higher positive DeltaBAIS2 values [Figure 1 (red ellipse)].

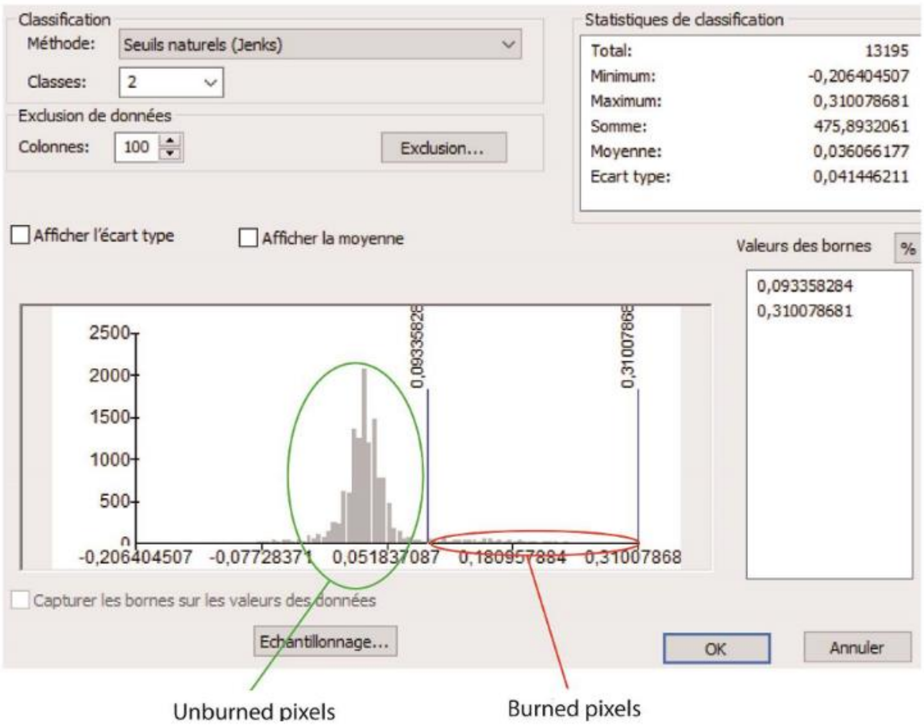

Figure 1: Histogram of deltaBAIS2 (16 Apr 20) on Prespa reedbeds.

In 2020 the natural threshold classification method was mostly used to identify the threshold value of dBAIS2 for discriminating burned from unburned areas (Figure 1). However, for 2021, we preferred to reclassify manually the pixels for each fire event. As many fires had small surfaces, we can hypothesize that the natural threshold model can no longer identify the burnt pixels as a class in its own right. So we chose to manually identify threshold values on the distribution histograms.

3. Results

In 2021, large-scale wildfire events were recorded and mapped in Prespa resulting in 67.5 hectares of burnt reedbeds (Table 2). The most severe event was recorded on May 6th in the Slatina Laimou/Slatina Plateos area with a total burned surface area of 36 ha (one fire/one date).

Four fires events burned a cumulated surface area of 18 ha in the area of Pyli.

Finally, the Karyes area has been impacted by 2 events (9,5 ha) and the Pump station area by one event (4 ha).

Table 2. Burned areas for each region from dBAIS2 analysis

Region	Surf. Area (ha)	Nb of pixels (20X20m)
Slatina Laimou/Slatina Plateos	36.04	901
Pyli	17.92	448
Karyes	9.56	239
Pump station	4	100

3.1. Fire events between 28/01 and 04/03/2021.

Delta BAIS2 was calculated using this formula: dBAIS2 = BAIS2 (04/03/2021) – BAIS2 (28/01/2021) (Figure 2). Considering the histogram of dBAIS2 values (Figure 3), the threshold value for the identification of wildfires was set at = 0.1 and the resulting map of burnt area is shown on figure 4.

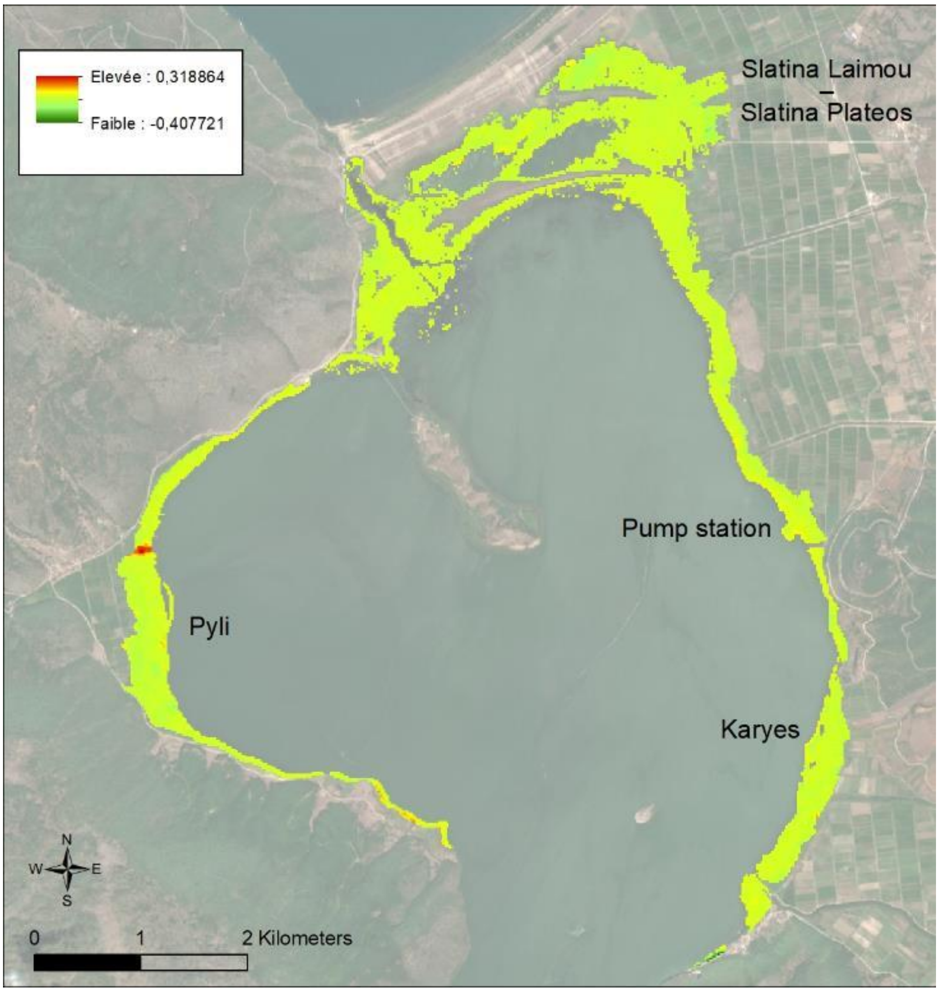

Figure 2. Delta BAIS2 (04/03 – 28/01/2021)

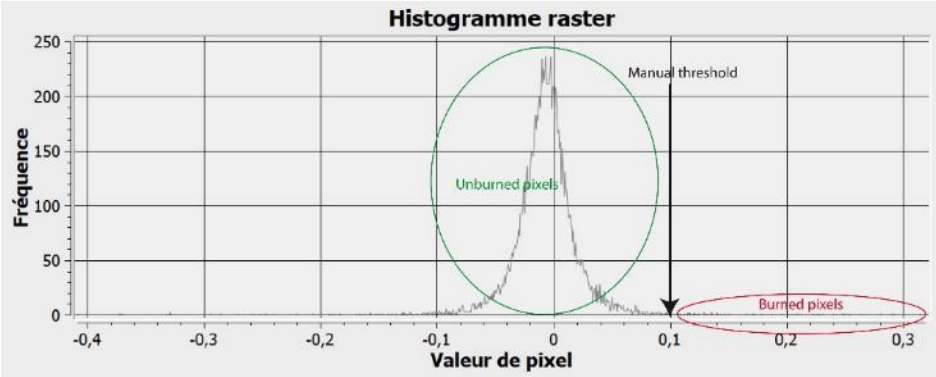

Figure 3. Histogram of Delta BAIS2 (04/03 – 28/01/2021)

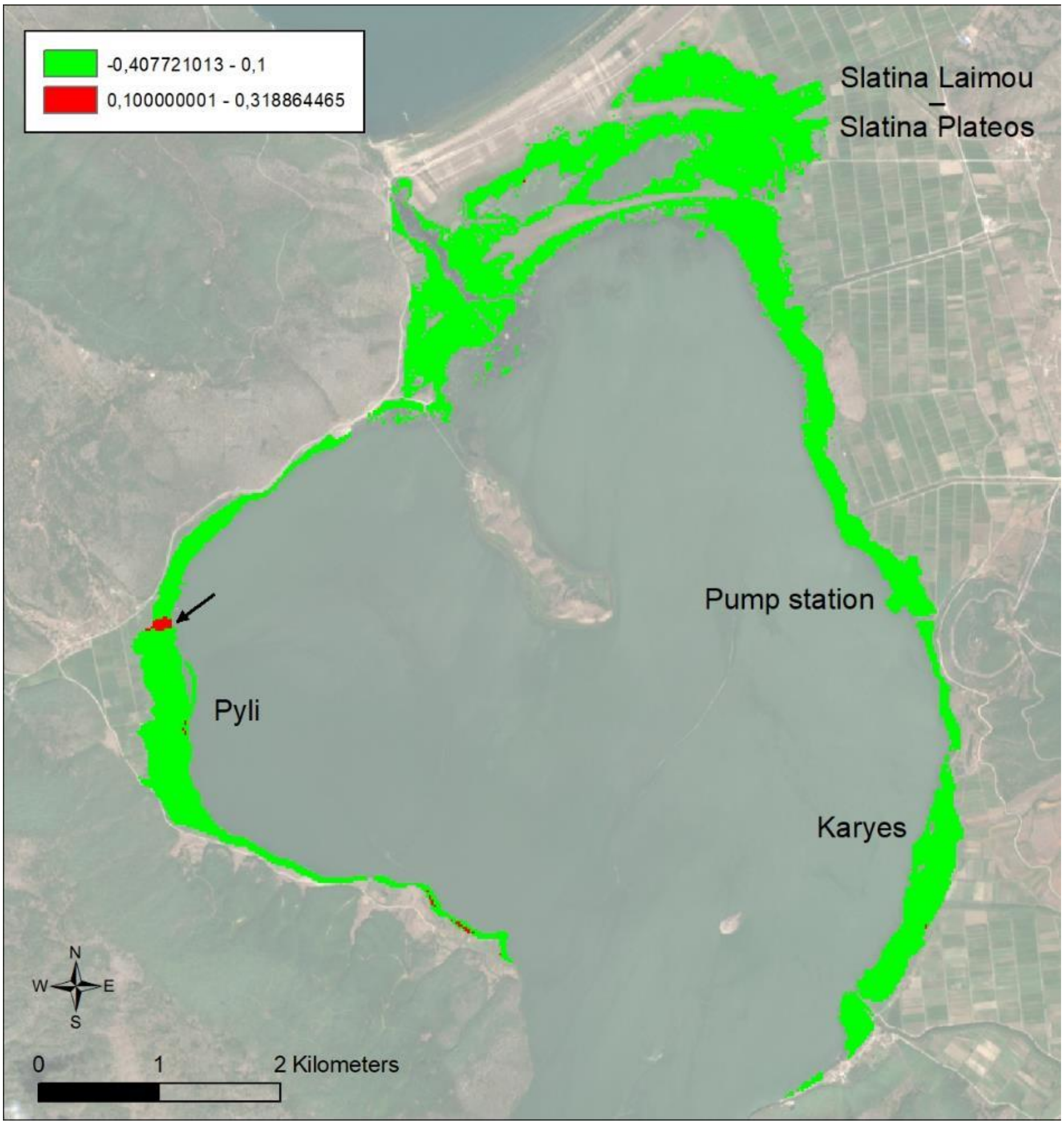

Figure 4. Classification of burned (red) and unburned (green) areas based on manual threshold method applied to Delta BAIS2 values (04/03 – 28/01/2021)

3.2. Fire events between 04/03 and 27/03/2021.

Delta BAIS2 was calculated using this formula: dBAIS2 = BAIS2 (27/03/2021) – BAIS2 (04/03/2021) (Figure 5). The threshold value for the identification of wildfires was set at = 0.1 (Figure 6). The resulting map of burnt area is shown on Figure 7.

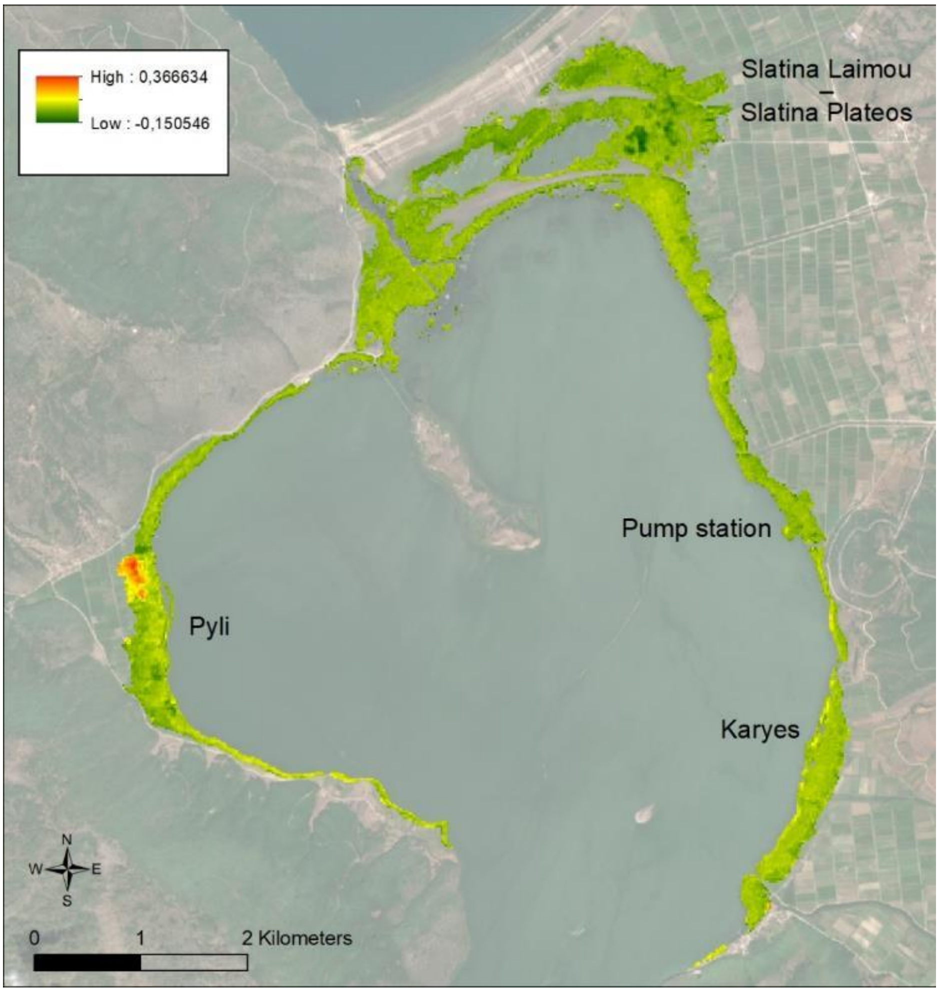

Figure 5. Delta BAIS2 (27/03 – 04/03/2021)

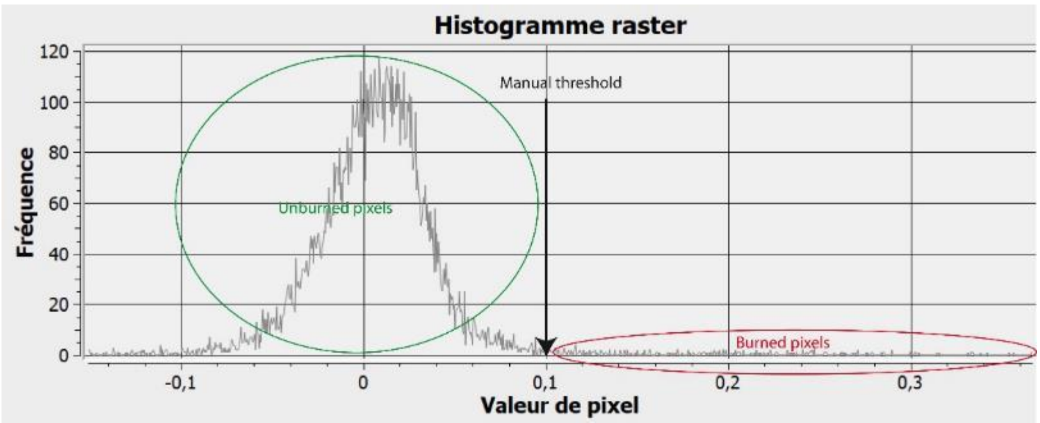

Figure 6. Histogram of Delta BAIS2 (27/03 – 04/03/2021)

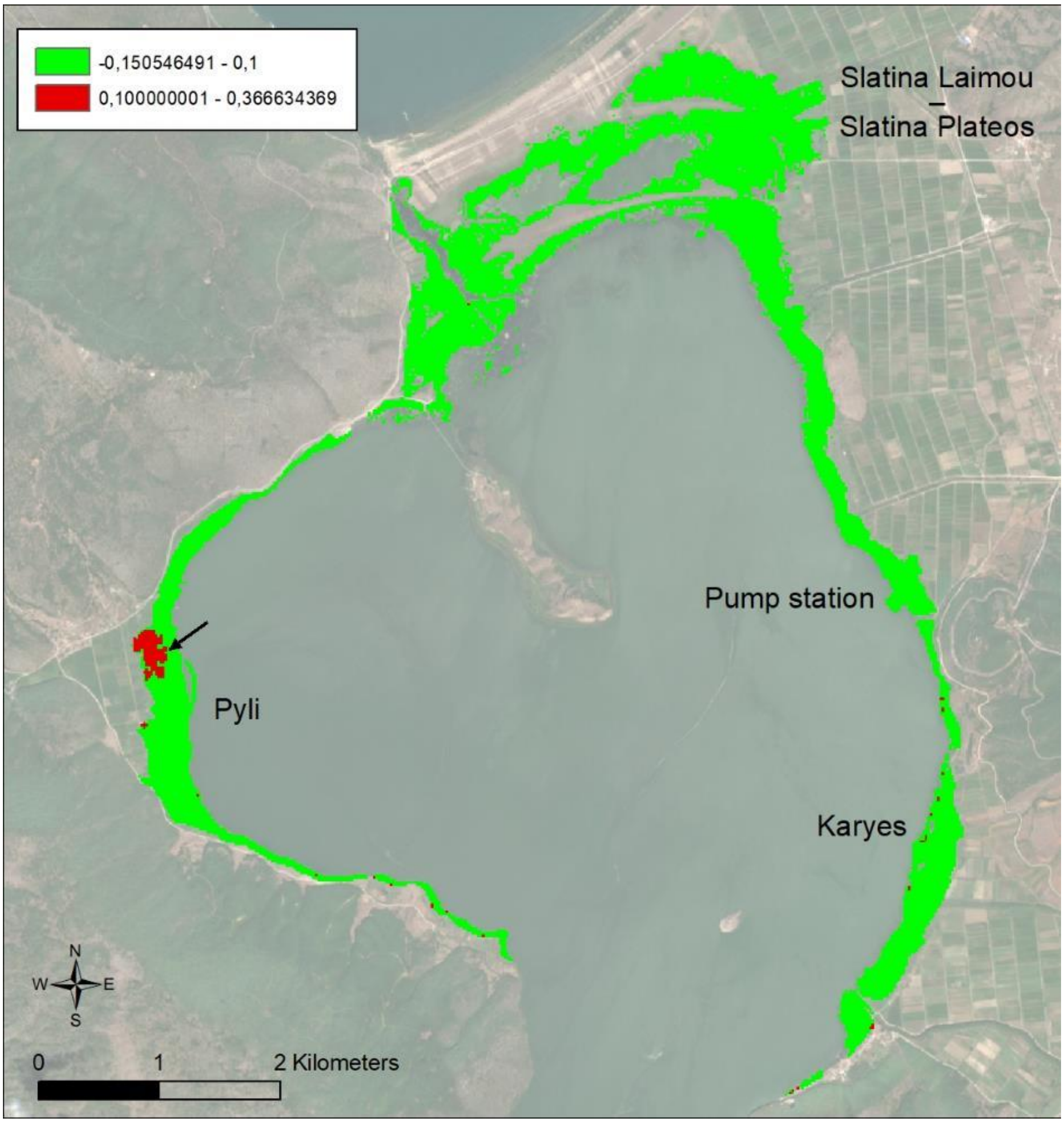

Figure 7. Classification of burned (red) and unburned (green) areas based on manual threshold method applied to Delta BAIS2 values (27/03 – 04/03/2021)

3.3. Fire events between 27/03 and 06/04/2021.

Delta BAIS2 was calculated using this formula: dBAIS2 = BAIS2 (06/04/2021) – BAIS2 (27/03/2021). (Figure 8). The threshold value for the identification of wildfires was set at = 0.085 (Figure 9). The resulting map of burnt area is shown on Figure 10.

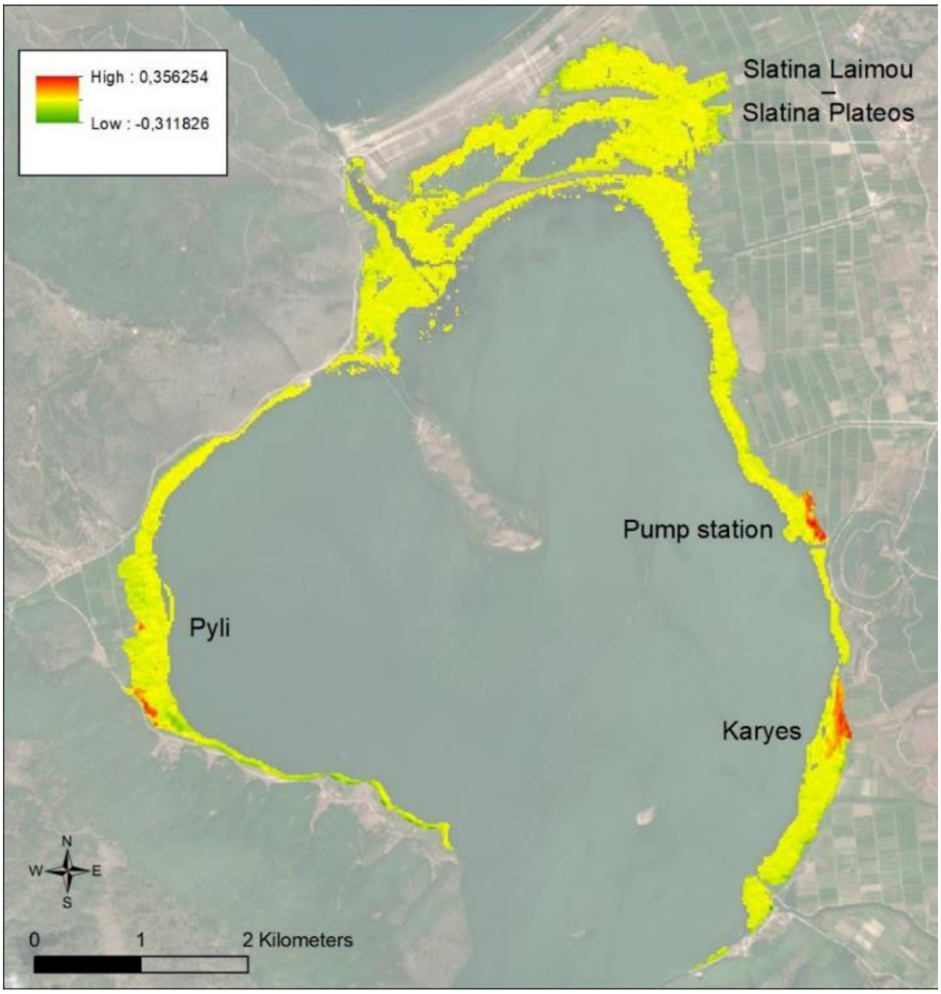

Figure 8. Delta BAIS2 (06/04 – 27/03/2021)

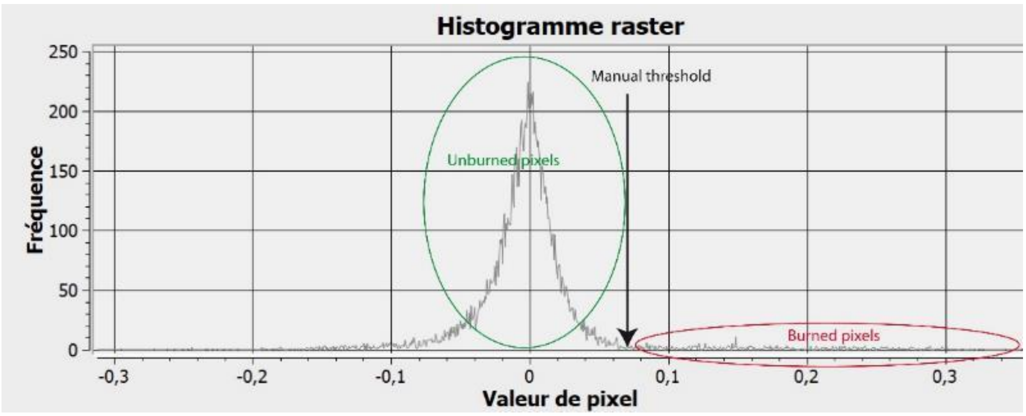

Figure 9. Histogram of Delta BAIS2 (06/04 – 27/03/2021)

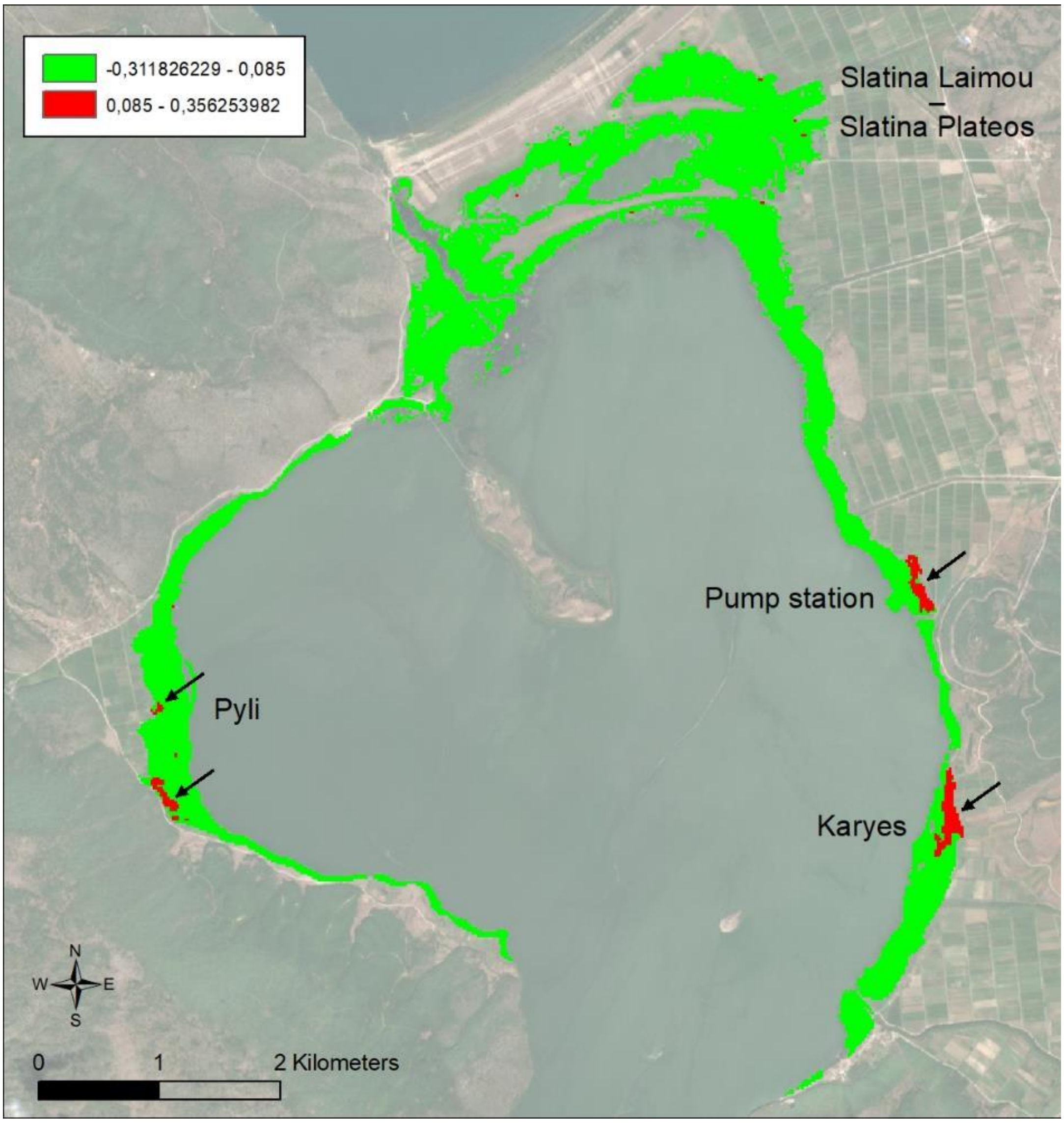

Figure 10. Classification of burned (red) and unburned (green) areas based on manual threshold method applied to Delta BAIS2 values (06/04 – 27/03/2021)

3.4. Fire events between 06/04 and 26/04/2021.

Delta BAIS2 was calculated using this formula: dBAIS2 = BAIS2 (26/04/2021) – BAIS2 (06/04/2021) (Figure 11). The threshold value for the identification of wildfires was set at = 0.08 (Figure 12). The resulting map of burnt area is shown on Figure 13.

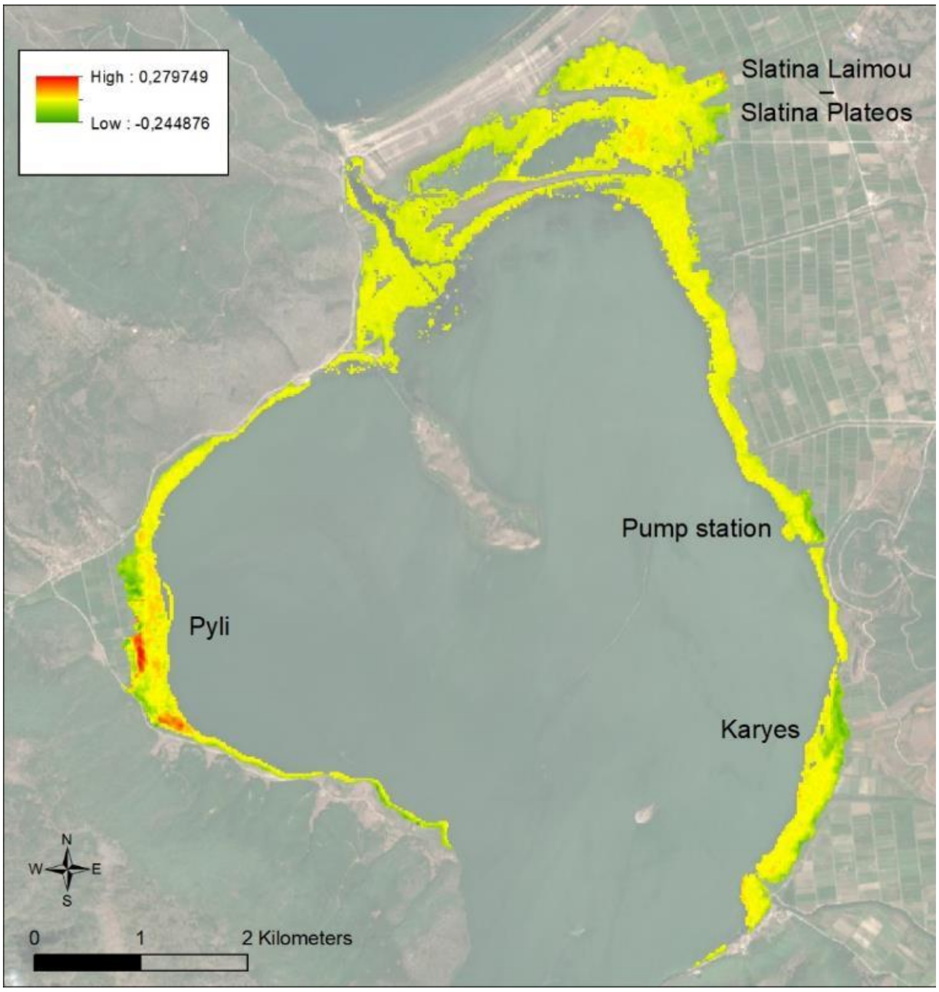

Figure 11. Delta BAIS2 (26/04 – 06/04/2021)

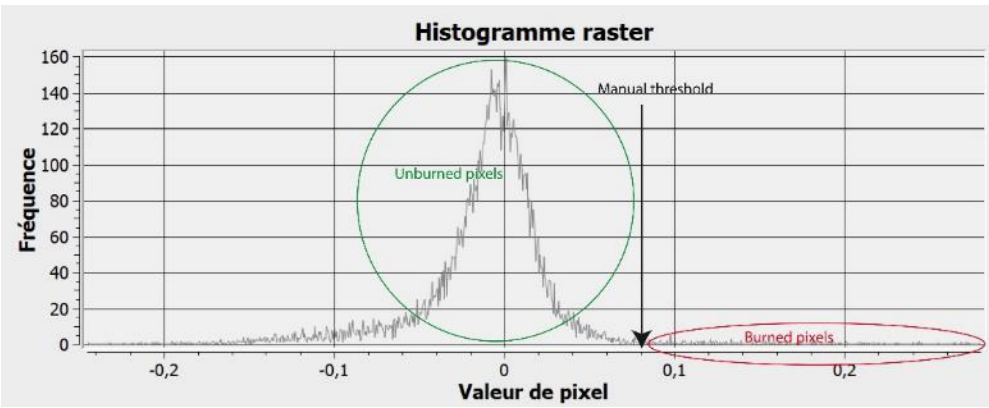

Figure 12. Histogram of Delta BAIS2 (26/04 – 06/04/2021)

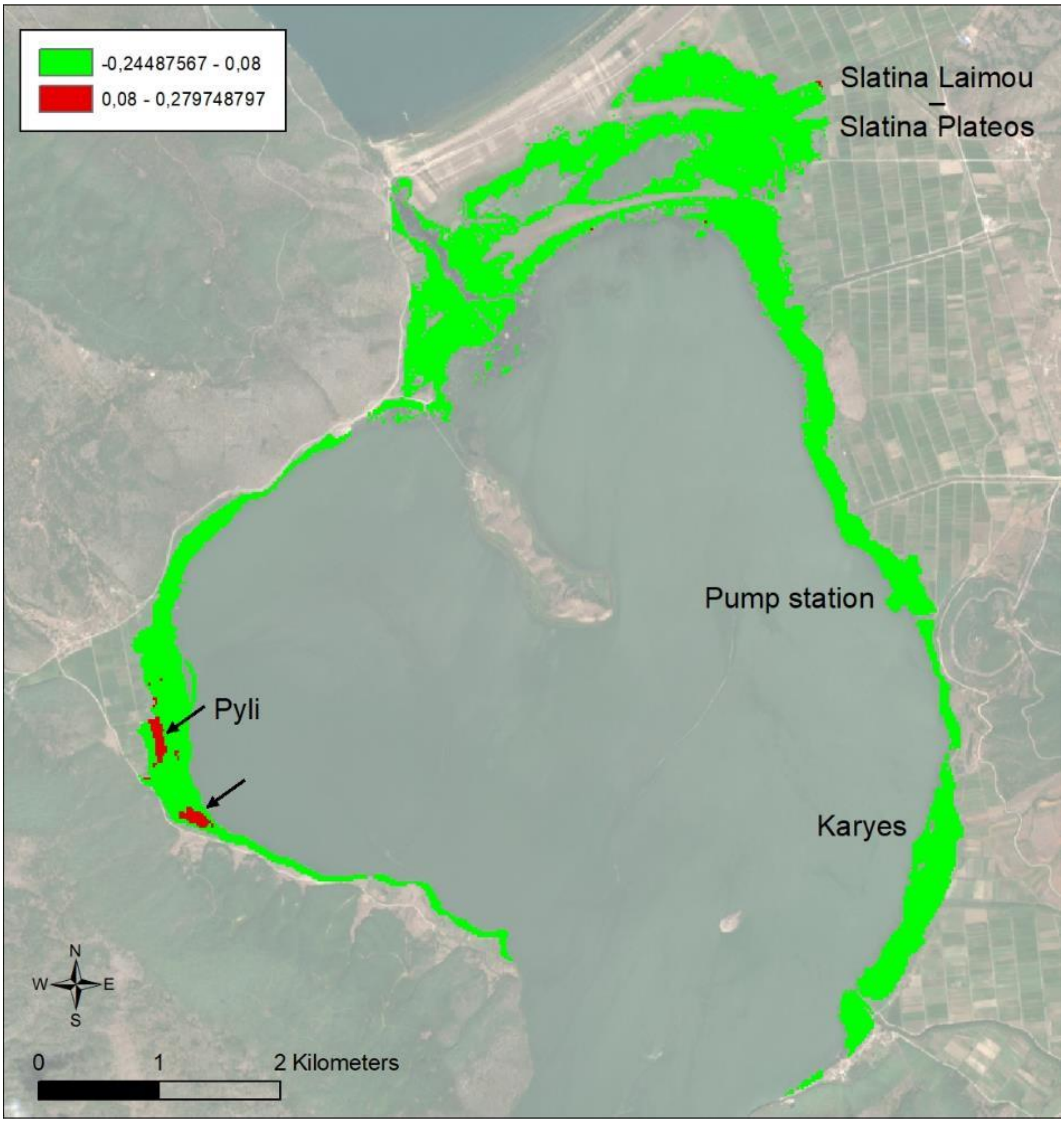

Figure 13. Classification of burned (red) and unburned (green) areas based on manual threshold method applied to Delta BAIS2 values (26/04 – 06/04/2021)

3. 5. Fire events between 28/04 and 11/05/2021.

Delta BAIS2 was calculated using this formula: dBAIS2 = BAIS2 (11/05/2021) – BAIS2 (28/04/2021) (Figure 14). The threshold value for the identification of wildfires was set at = 0.1 (Figure 15). The resulting map of burnt area is shown on Figure 16.

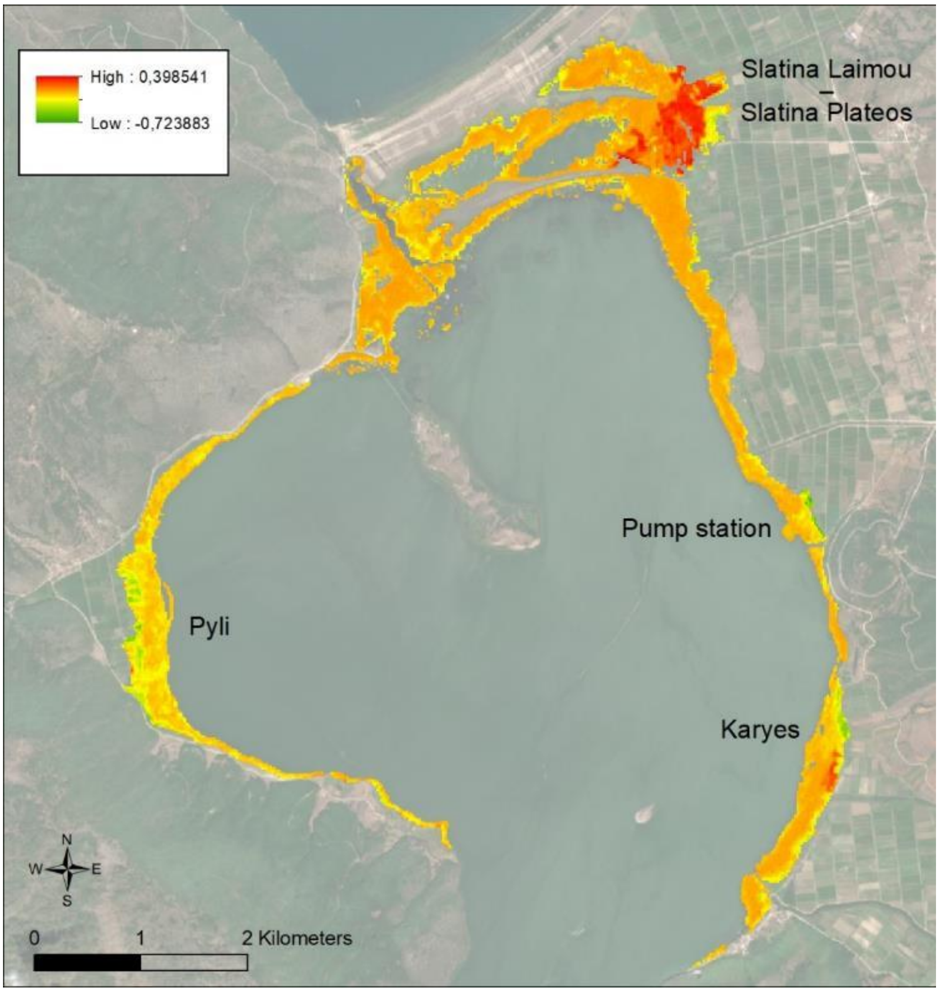

Figure 14. Delta BAIS2 (11/05 – 28/04/2021)

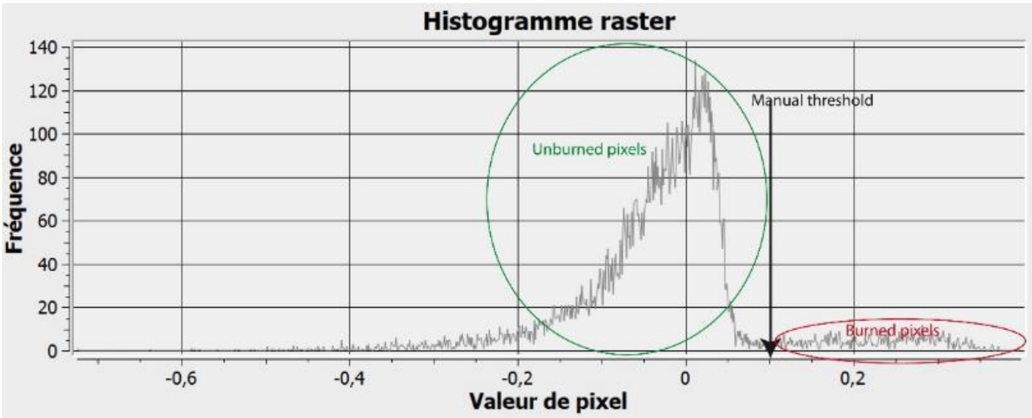

Figure 15. Histogram of Delta BAIS2 (11/05 – 28/04/2021)

Based on this histogram, manual threshold was set at value = 0,1.

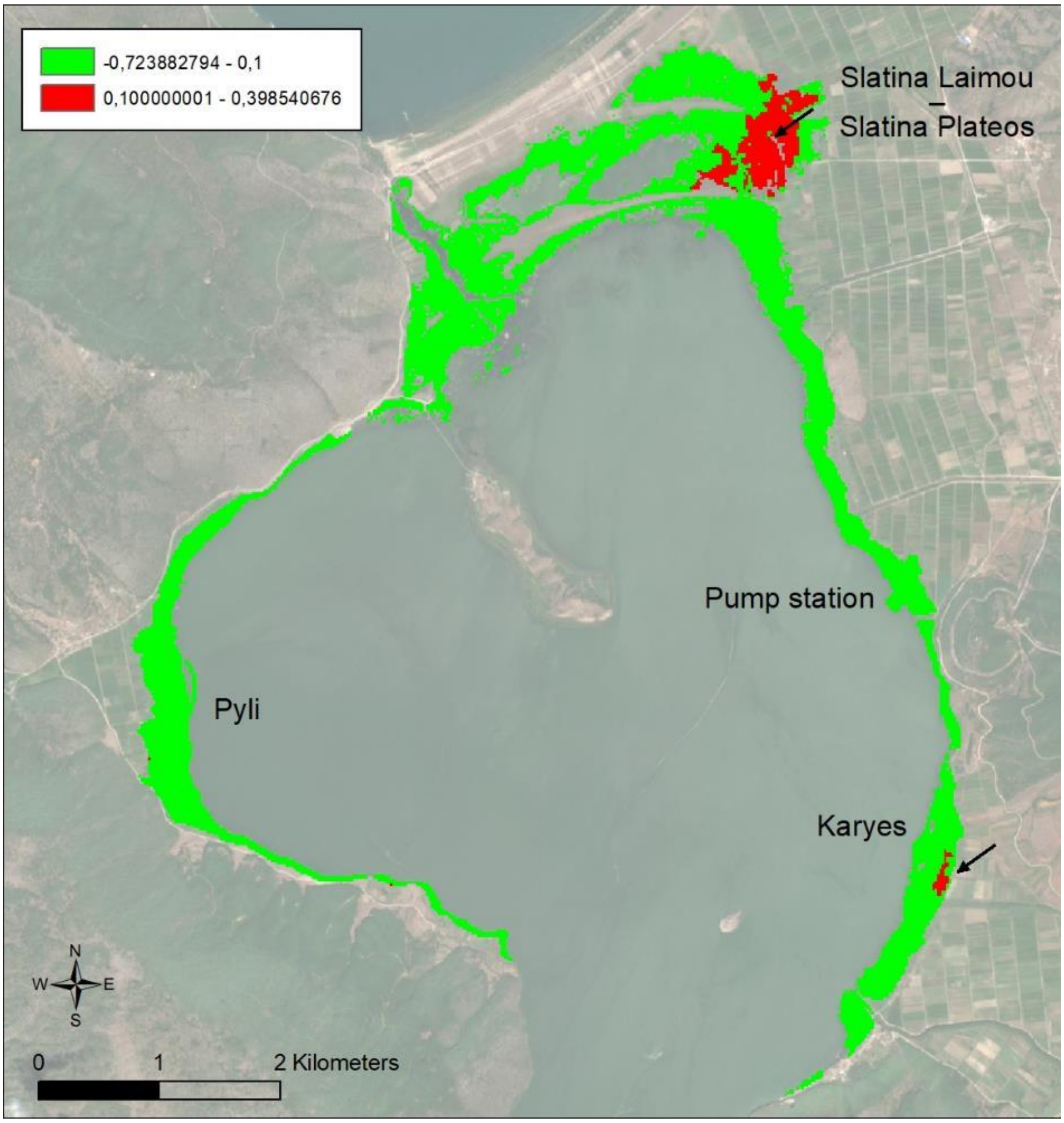

Figure 16. Classification of burned (red) and unburned (green) areas based on manual threshold method applied to Delta BAIS2 values (11/05 – 28/04/2021)

4 – Additional analysis : use of drone photos for mapping wildfires areas.

4.1 - Methodology

Oblique photos from drone missions can be useful and complementary to the dBAIS2 method for mapping reedbed burned areas, providing large number of reference points for burned and unburned areas. The methodology is described in the annex.

GIS software, like ArcMap (ESRI), has many projections/georeferencing tools of images (.jpg, .bmp, .tif, etc). One of these tools is dedicated to the « redress» and « re-flattening » of aerial oblique photos.

Even if this tool is not completely perfect (it is working on image distortions), it has shown that it is relatively precise compared to satellite analysis or even field mapping. Tour du Valat is mapping annually Camargue reed harvest from plane aerial pictures with this method since 2013.

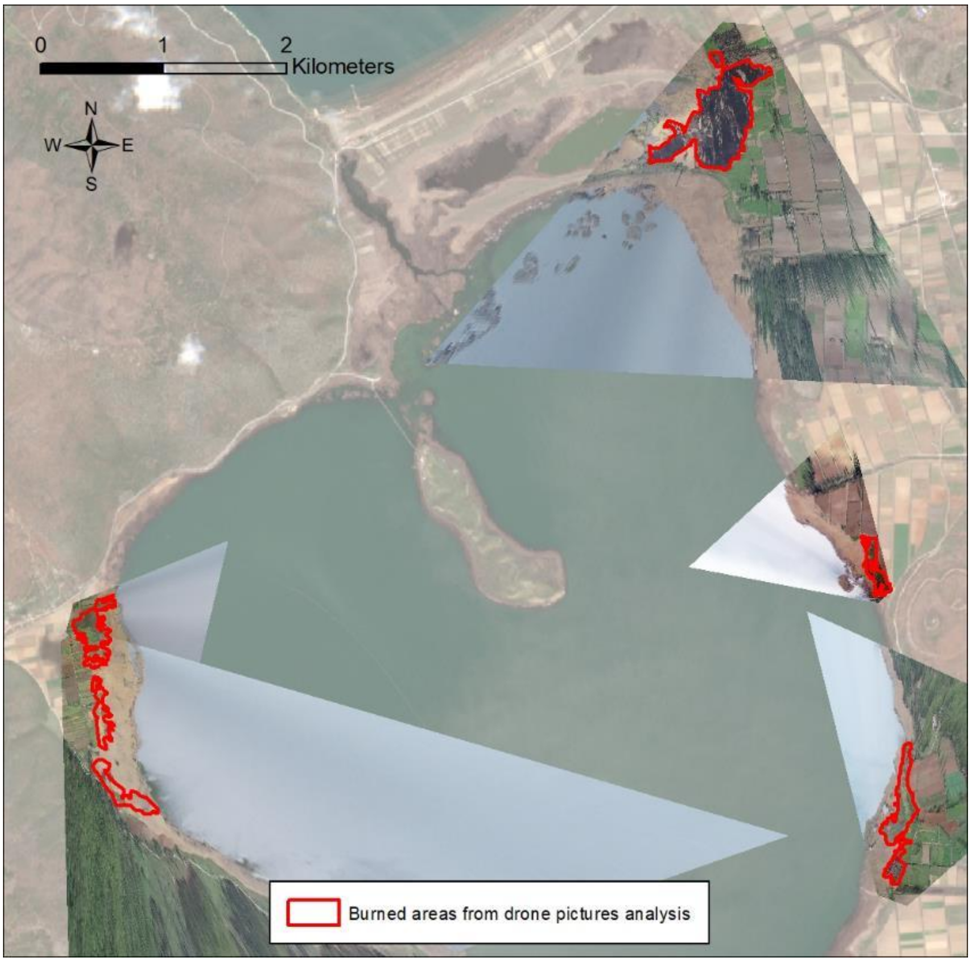

Figure 17. Burned areas from drone pictures analysis

NB: Drone pictures of the south of Pyli were missing, appearing only in the far background of photos of northern Pyli. So the southernmost polygon drawn on Pyli was still drawn but it is far from being precise.

4.2 – Results

Using drone images, the total surface area burnt was estimated at 74ha (Table 3). The surface areas calculated from drone surface areas are 10% bigger (range 5 – 26%) than those calculated using the SENTINEL-2 methods (dBAIS2) (Table 3). The overlap between areas identified by both methods is very high (Figure 18). The delineation of the burned polygons from the drone images does not make it possible to distinguish the sub-zones which were not reedbeds within the burned areas. This may at least partly explain the 5-26% overestimation of surfaces in the drone technique.

Conversely, while dBAIS2 analysis measured and counted areas on a 20 m x 20 m pixel base, the drone method measures areas on drawn polygons, that could be more precise and accurate, especially on the edges.

Table 3. Burned areas for each region from drone pictures analysis and comparison with results using Delta BAIS-2 method.

Region	Drone Surf. Area (ha)	dBAIS2 Surf area (ha)	Difference (%)
Slatina Laimou/Slatina Plateos	38.55	36.04	7.0
Pyli	19.51	17.92	8.9
Karyes	12.07	9.56	26.3
Pump station	4.21	4	5.3
Total	74.34	67.52	10.1

Figure 18. Burned areas from dBAIS2 analysis & from drone pictures analysis

Literature

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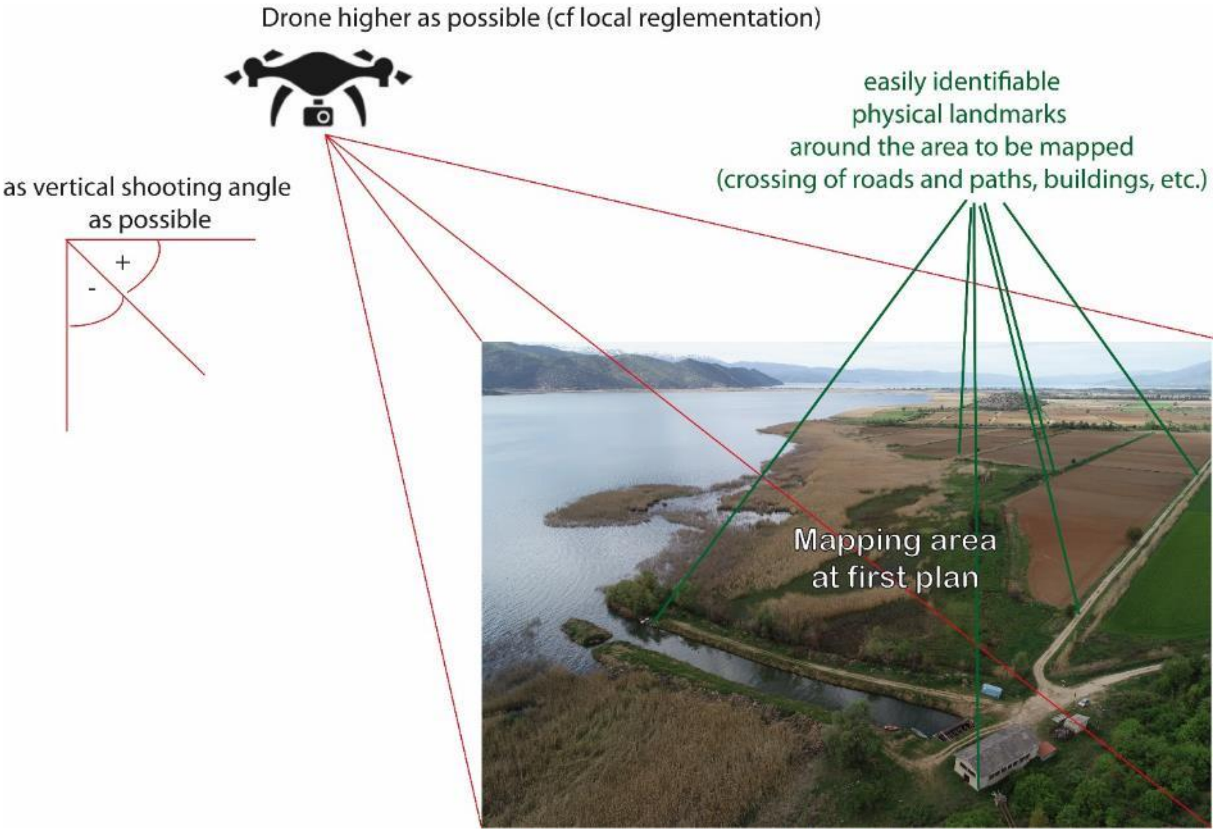
Annex: methodology of mapping from drone (or any aerial) photos

A - Optimization of drone photos



Visualization of optimal drone captures

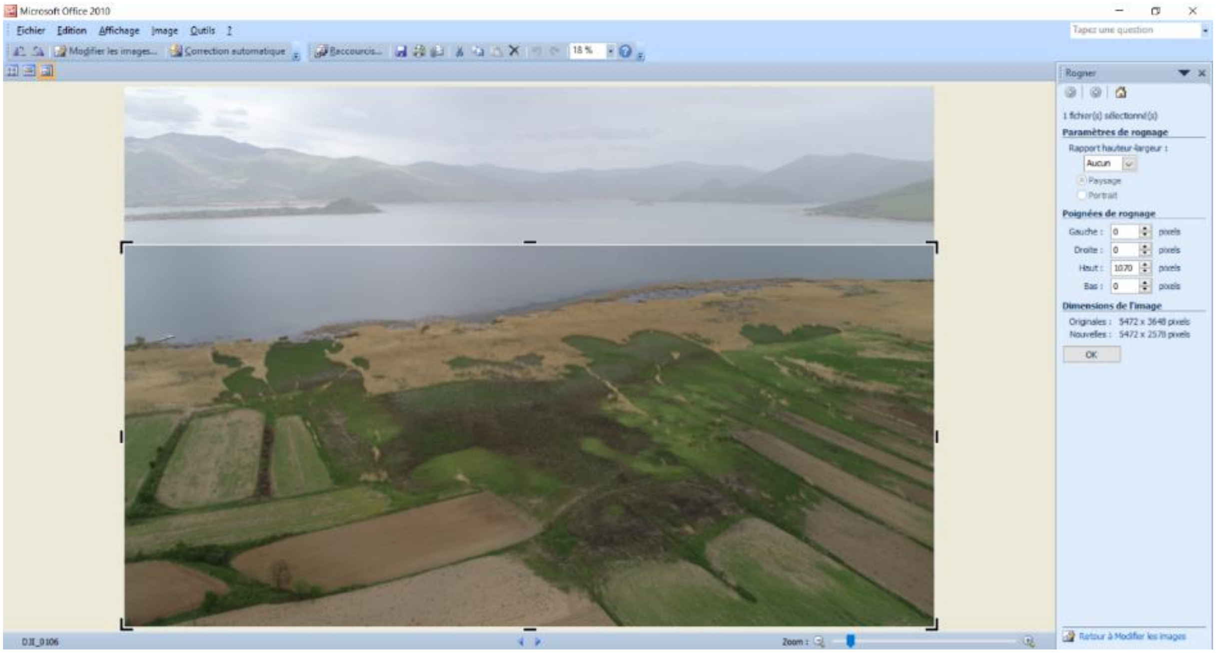
The mapping zone should be capture at first plan more as possible. If the area to be mapped is too large in length, the drone will have to take several photos spread over the area.

The drone should be higher as possible and take as vertical a shooting angle as possible. It is necessary to minimize the photos which would be too "flat".

The photos need to have easily identifiable landmarks around the area: these points will serve as control points to project and transform the photos.

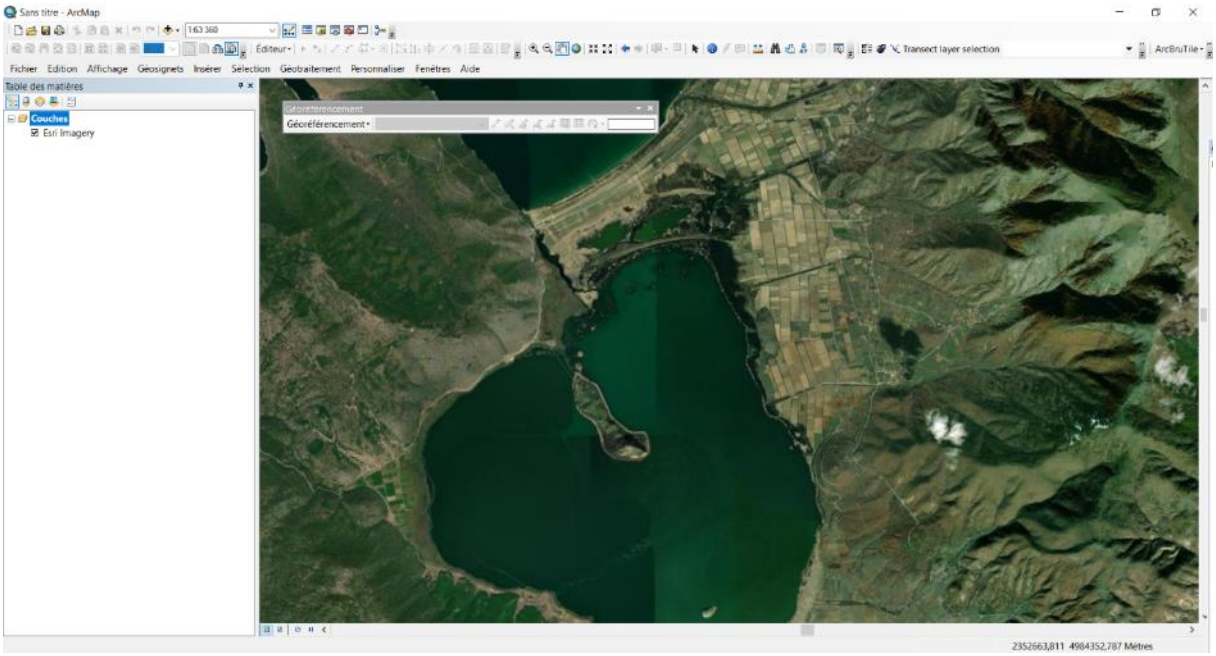
B – Georeferencing drone photos

Prepare your photo by cutting out the background and the horizon and save it as a new jpg file.

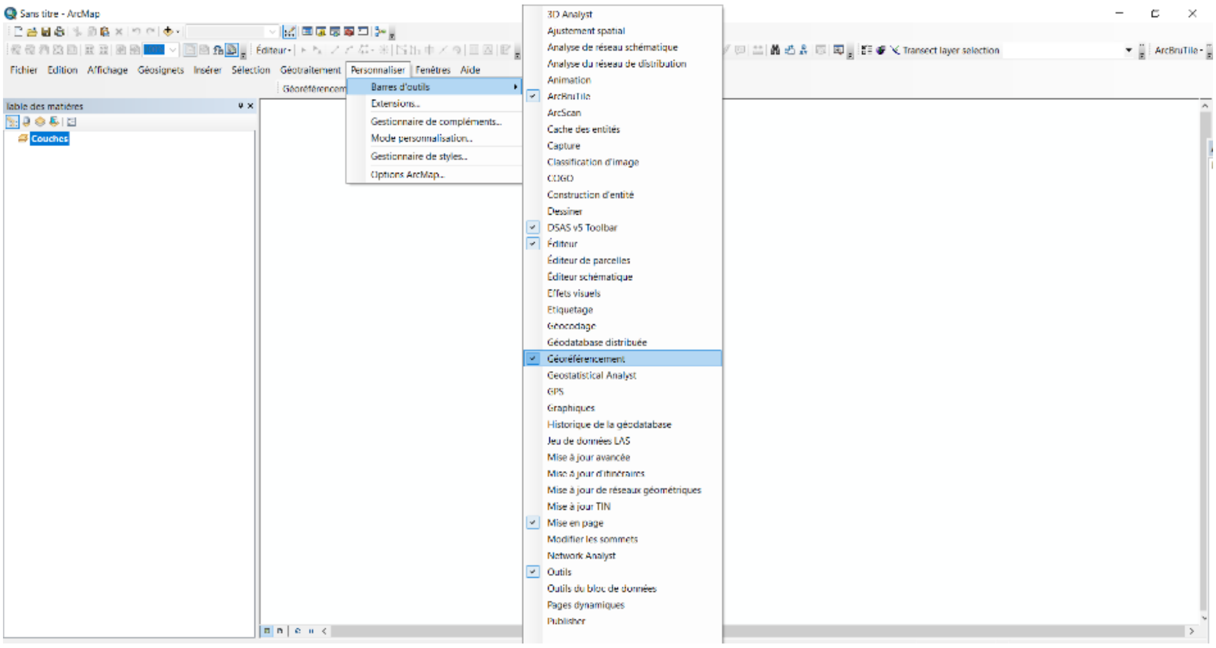


Open ArcMap.

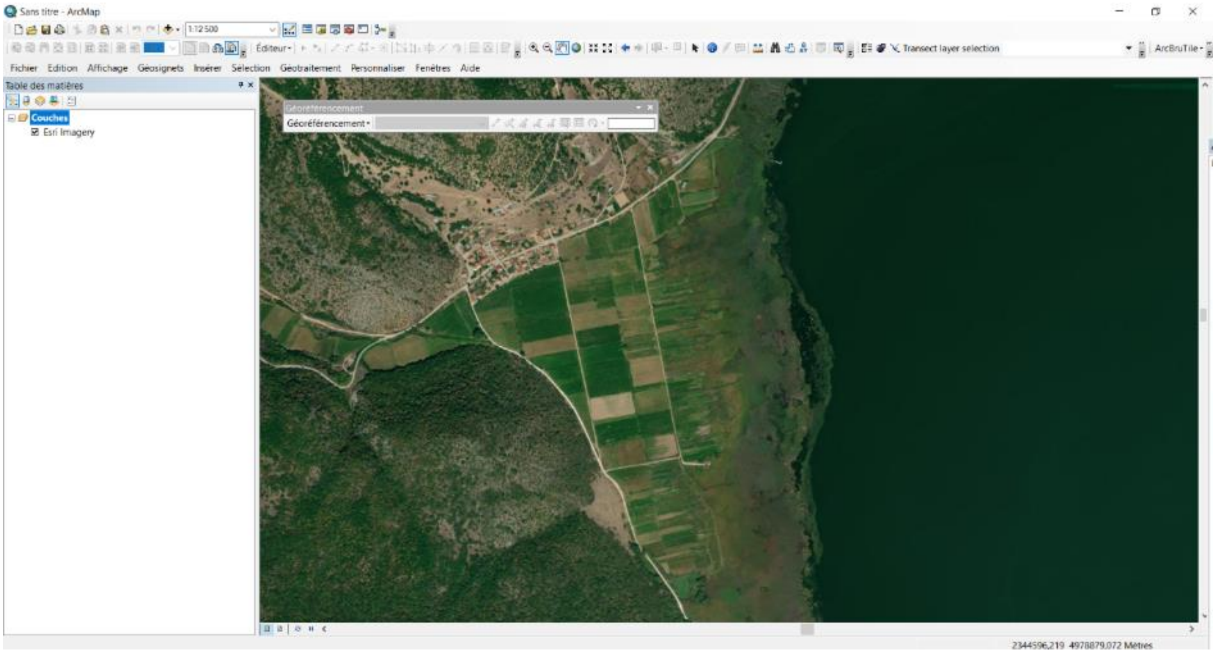
First, open a georeferenced background.



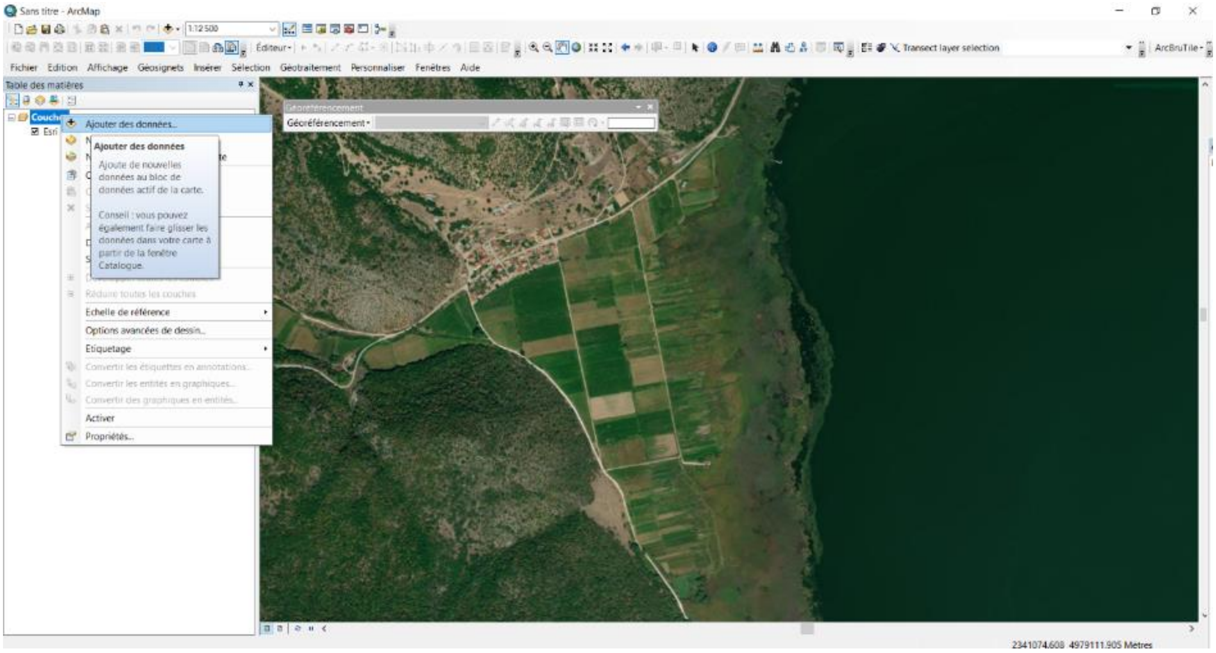
The Georeferencing tool from ArcGis is used.

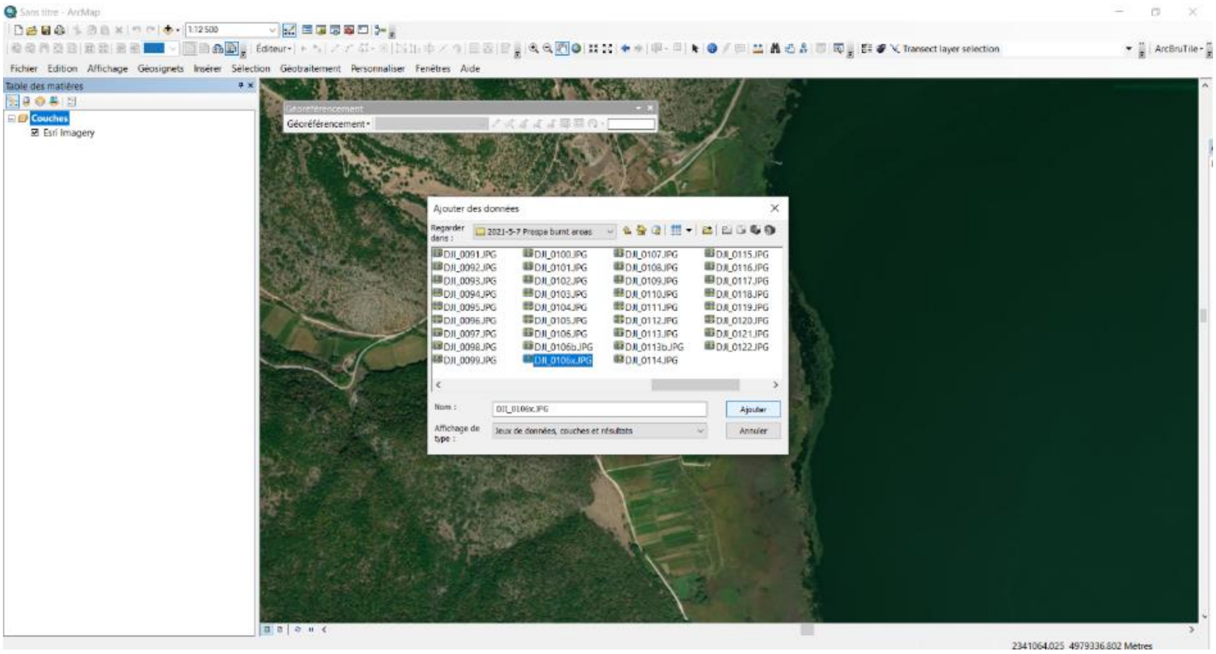


Move around the background map to find yourself roughly in the area of the drone photo to georeference.

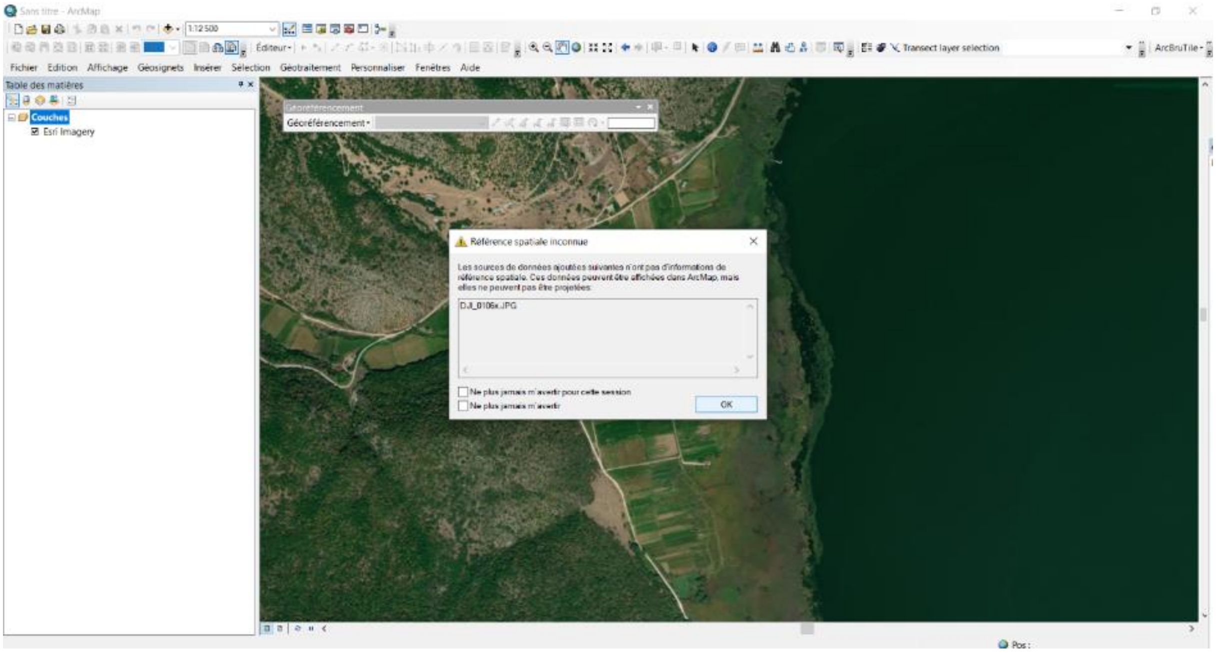


Add new file : your jpg drone photo

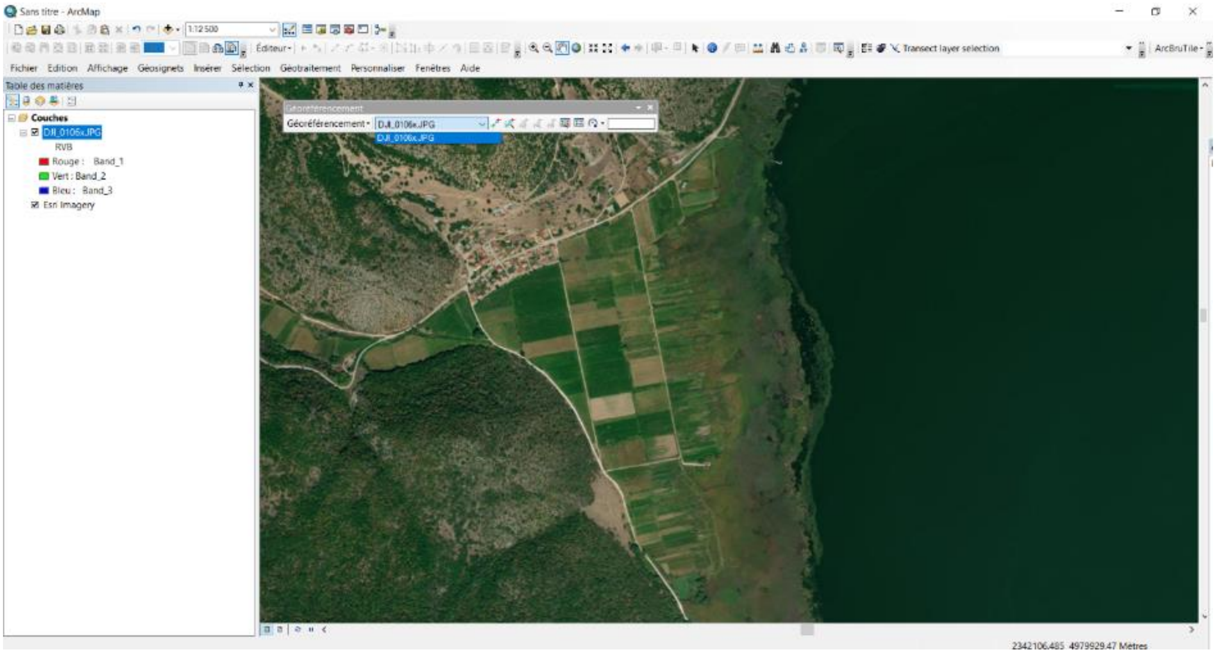




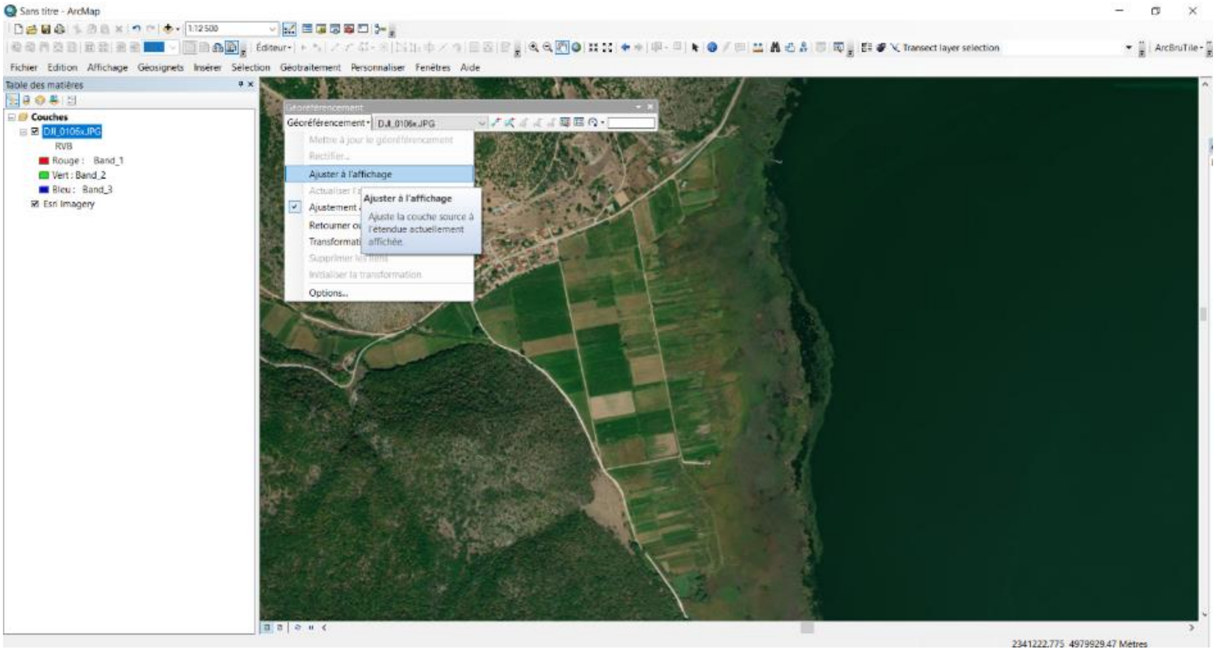
ArcMap warns that data sources have no spatial reference. These data can be displayed but cannot be projected.



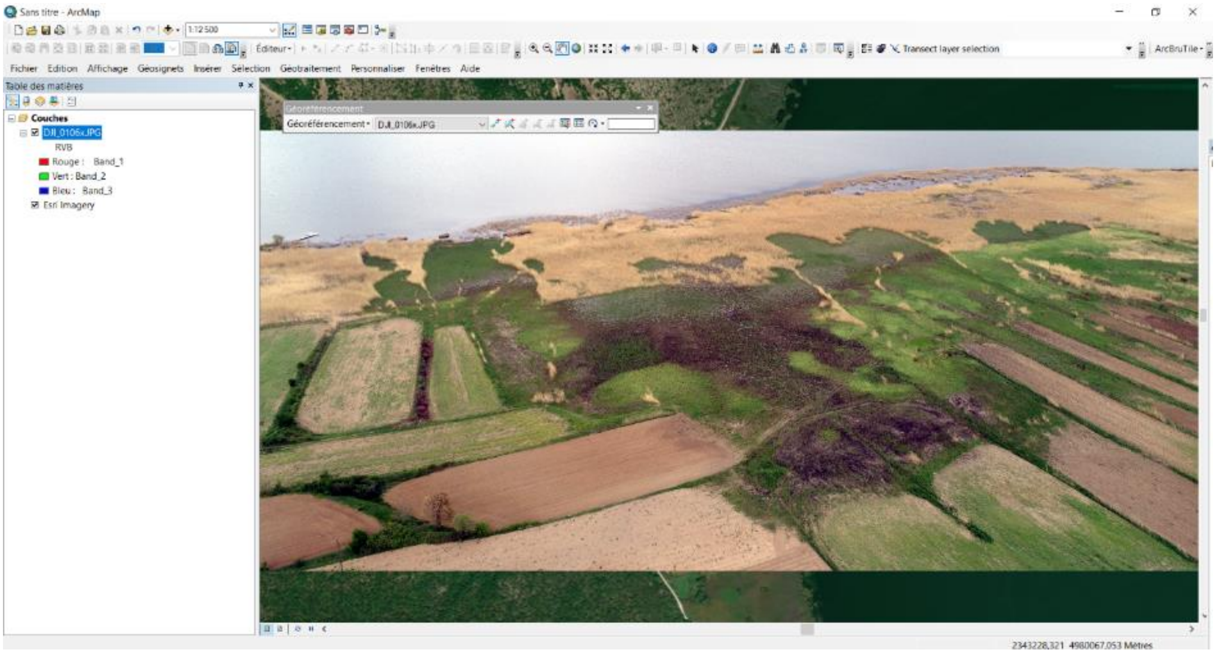
Select in Georeferencement tool the jpg file to be referenced.



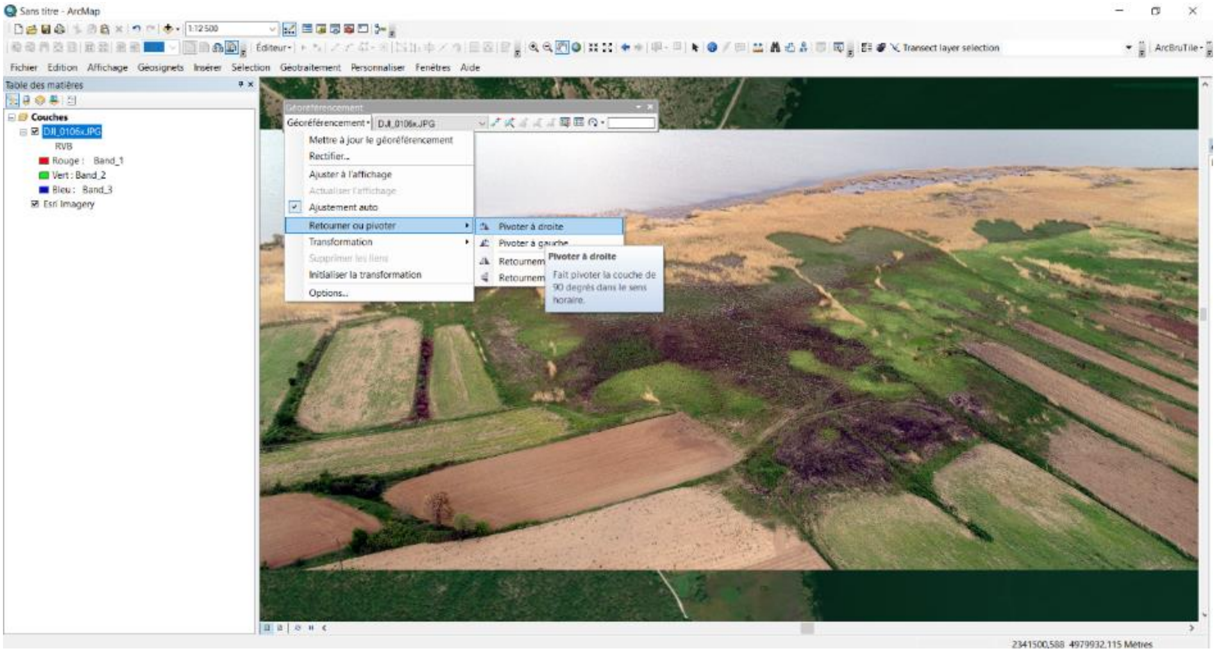
Georeferencement => fit to display your jpg file.

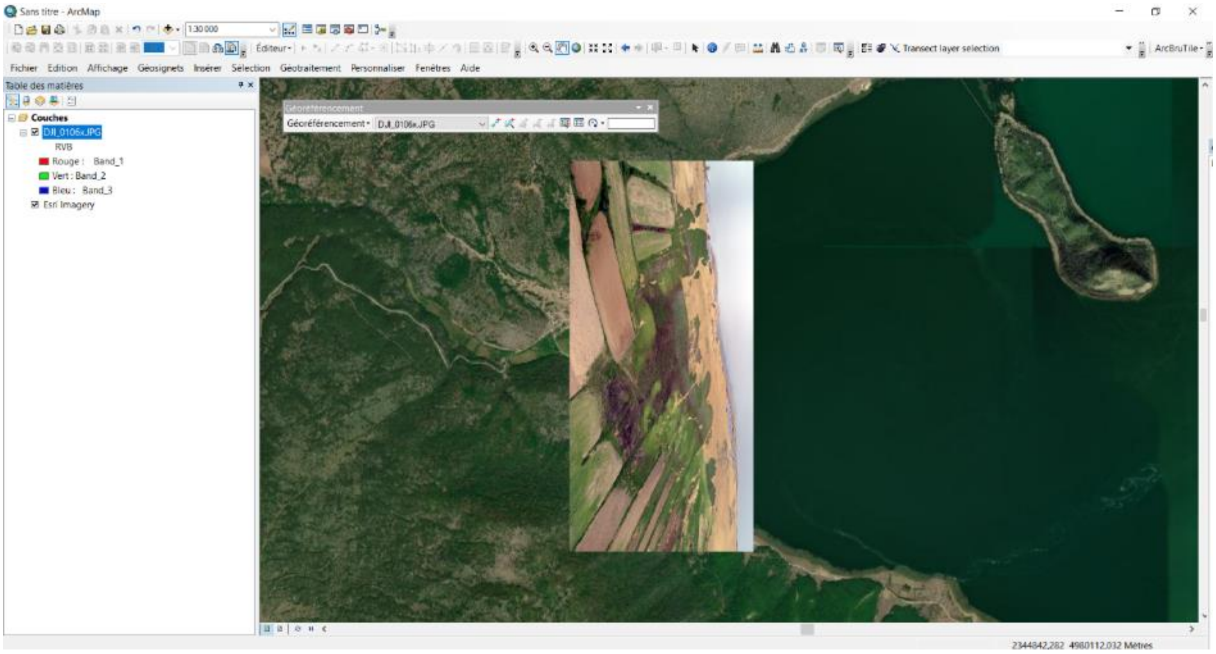


The jpg file appears above your background map.

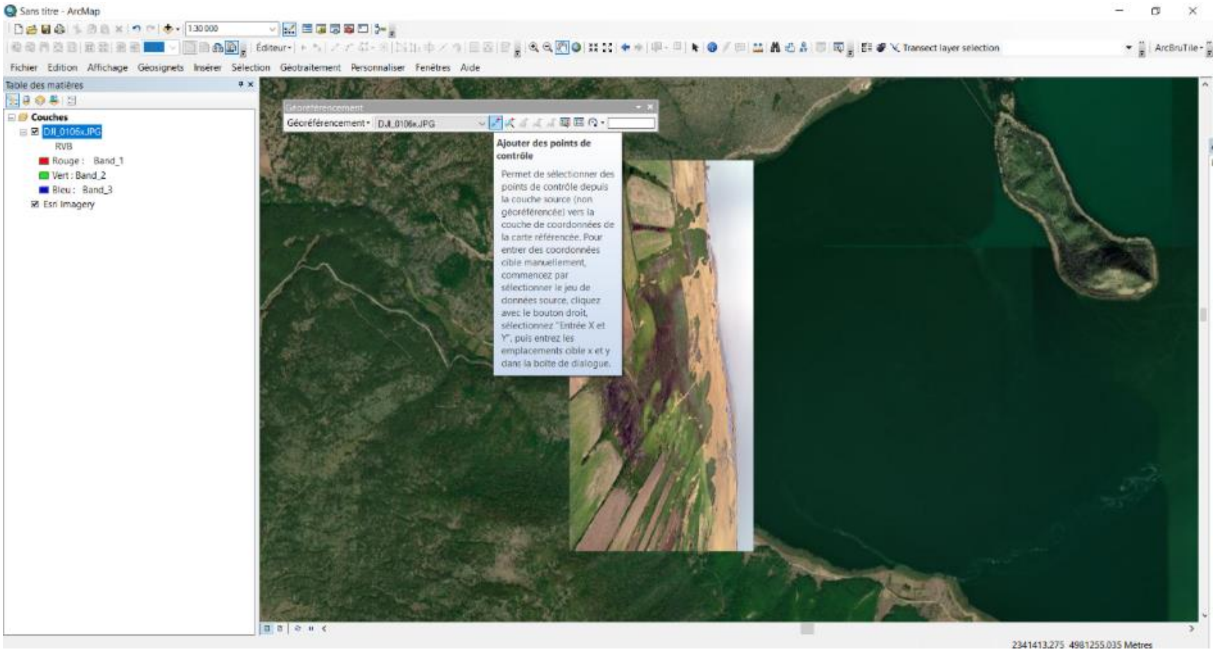


As the photo was taken at a rather west-east oriented angle, turn the photo by 90 ° on the right.

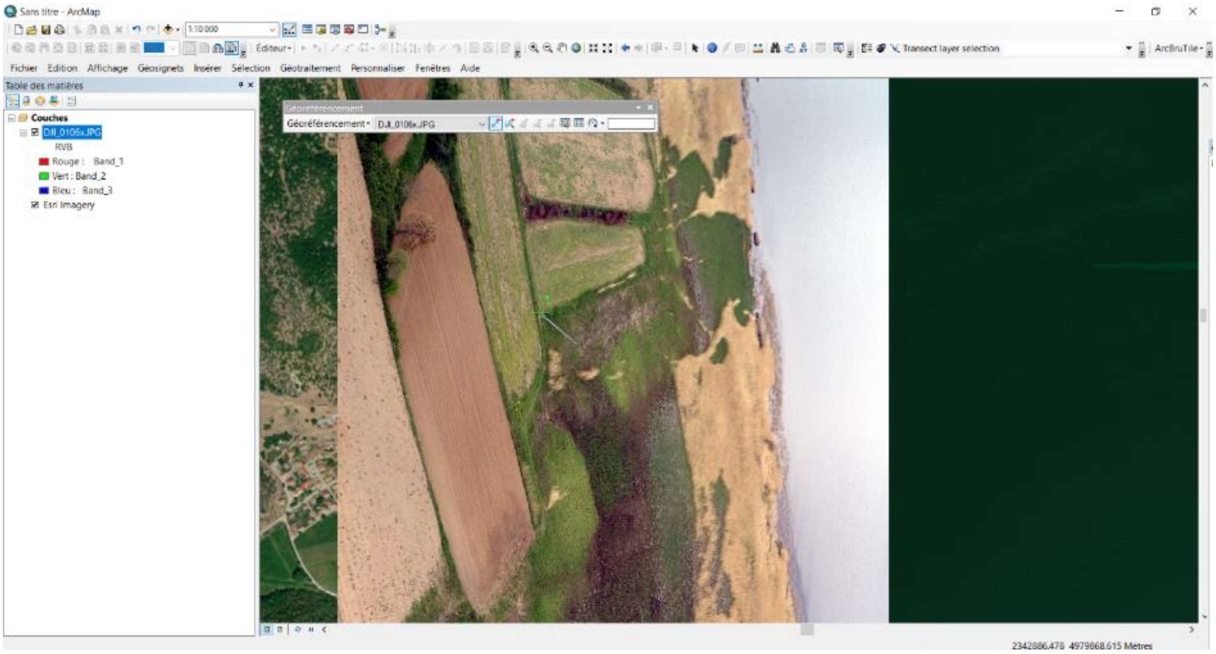




Now you have to add control points.

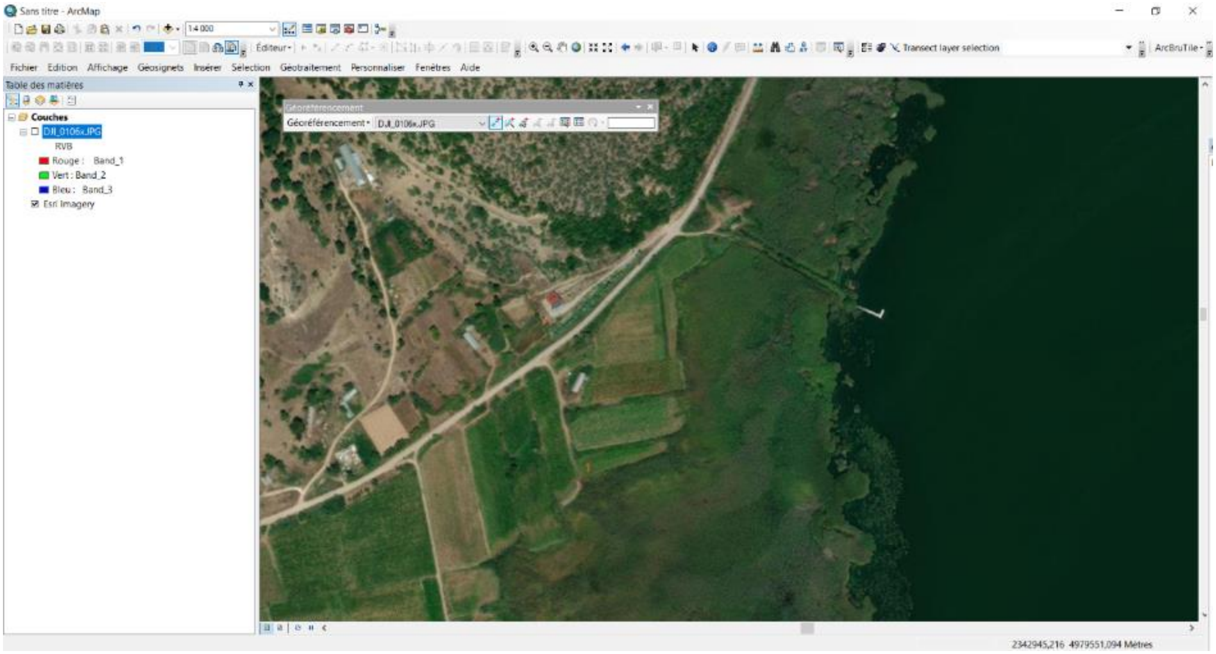


First, click on the jpg file on an identifiable landmark. It displays a green cross.

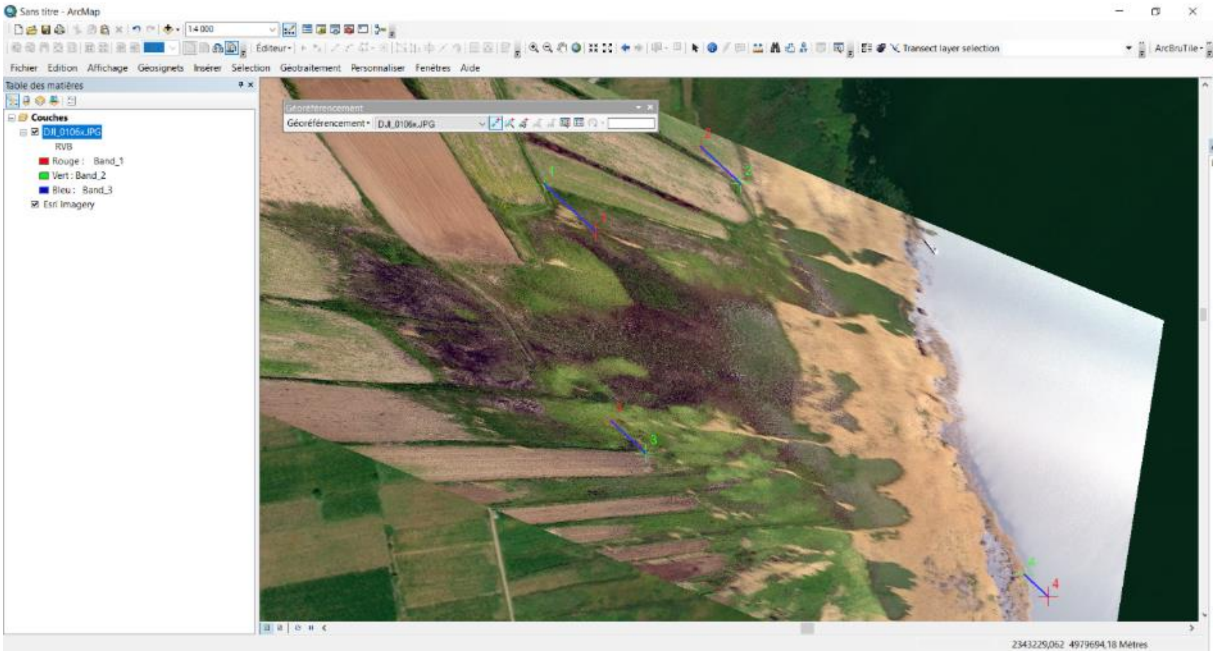


Unclick the jpg file to make it invisible, and to see only the reference background.

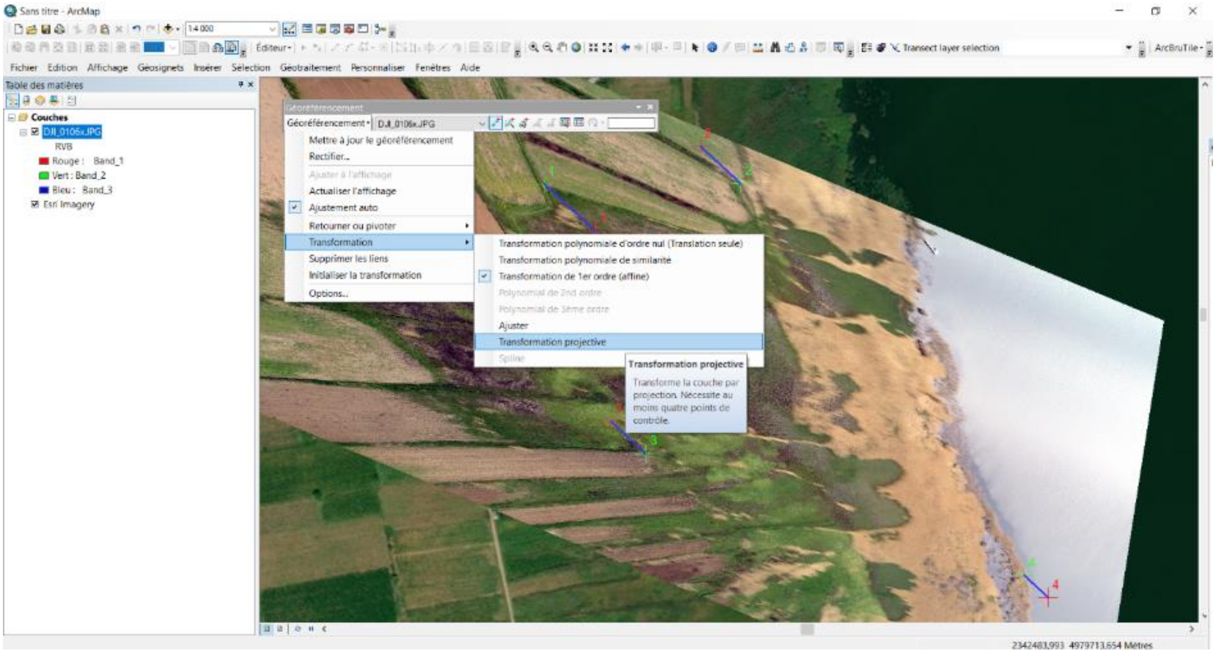
Click on the same landmark on the reference background: it displays a red cross.

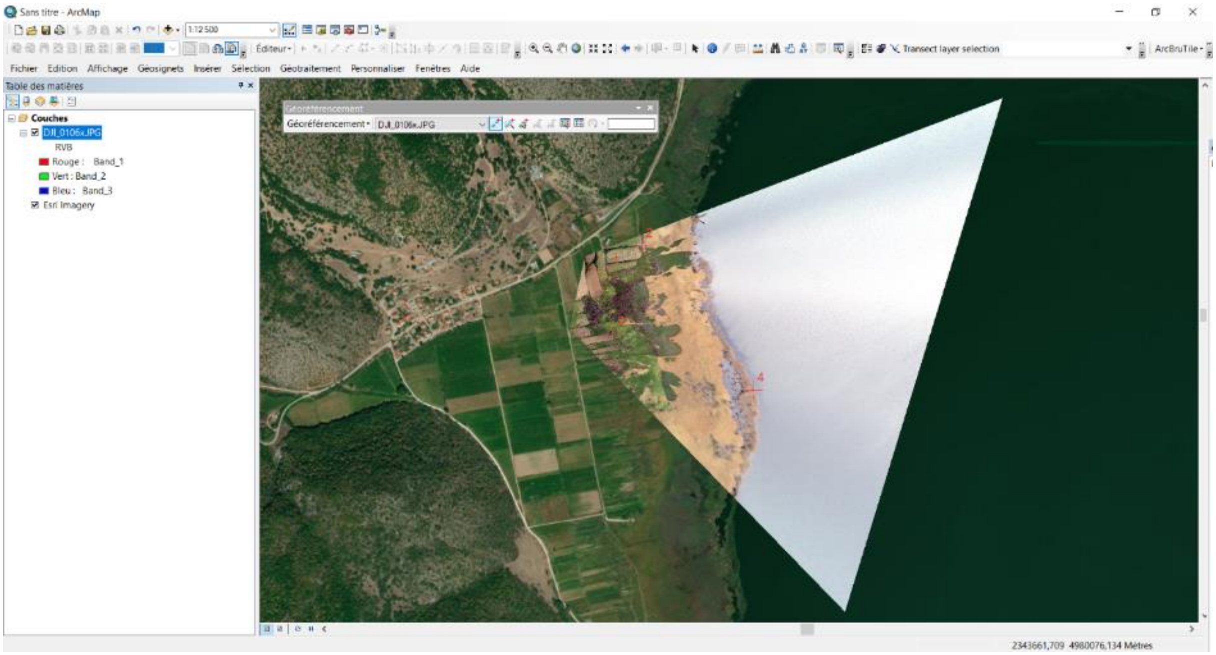


Repeat the same operation until <u>at least 4 control points</u> are obtained, trying to distribute them evenly in the jpg image.



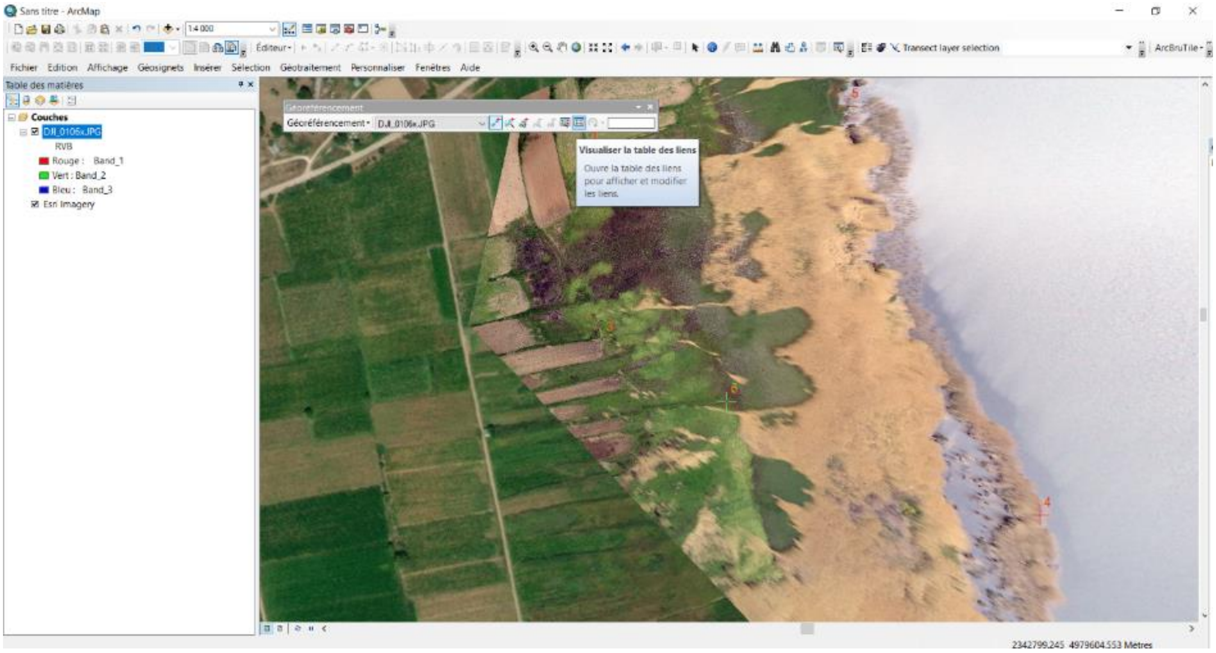
From the moment you have at least 4 control points, you have access to a transformation mode: the projective transformation.

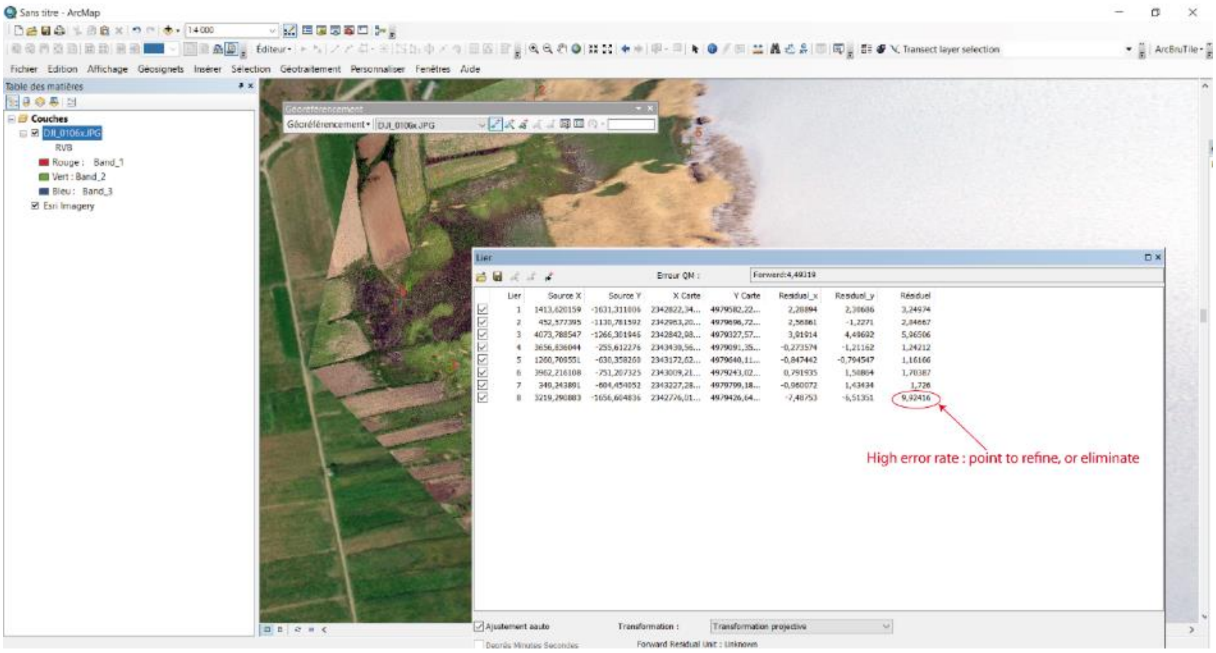




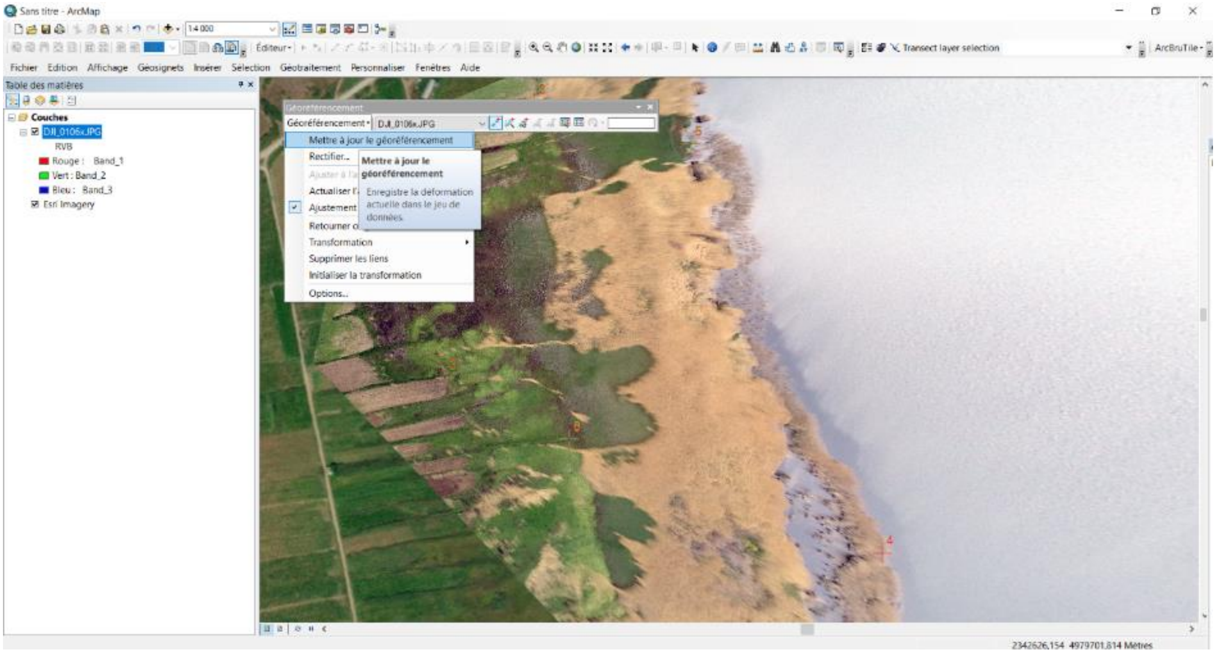
Now that you have your projected jpg, you can refine, add additional points, and eliminate in the table of links the control points that may have too high an error rate.

NB: Projective transformation only gives good results on flat areas. The control points must always be taken in the plain, never on the surrounding hills and reliefs.





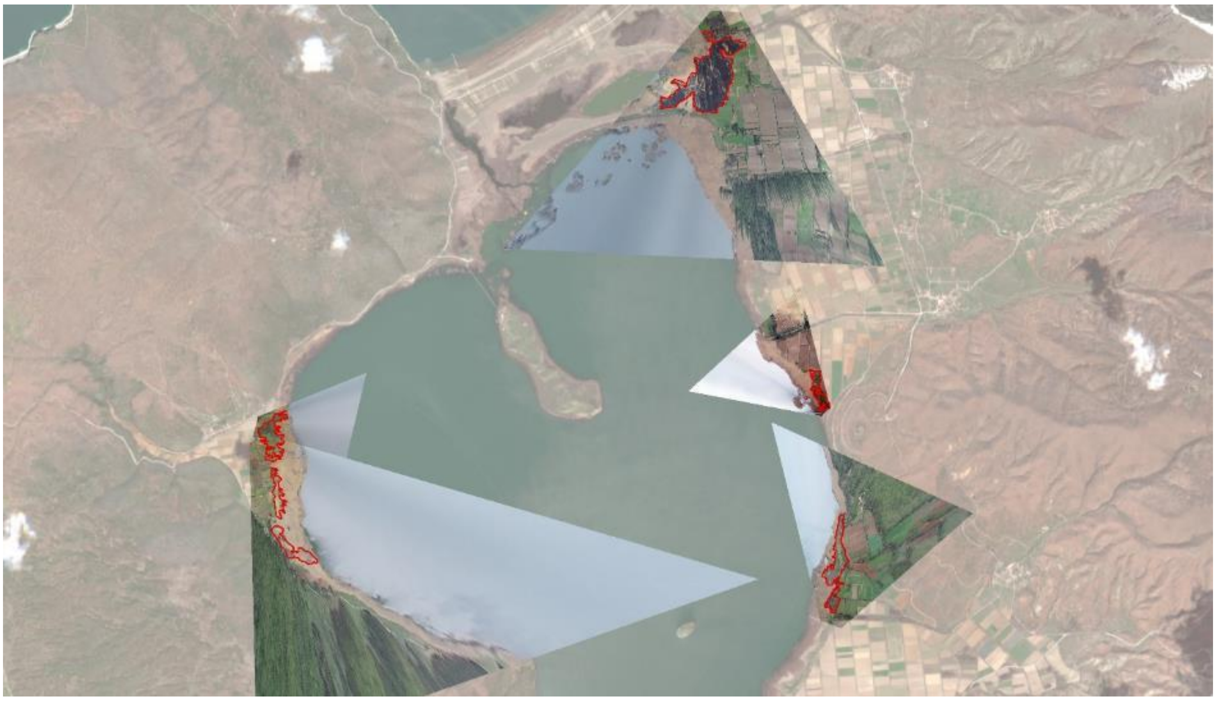
At last, when you consider that your control points are ok, save your georeferencement. ArcMap will save auxiliary files in your jpg folder.



Now that you have saved your georeferencement, you can close/re-open your jpg file, it will be always re-projected properly.

C – Drawing burned areas

After your drone photos re-projected, you can digitalize in .shp your burned areas :



To be even more accurate, you can adjust a correction when you draw your polygons to delineate the part hidden by the height of the reed, according to the position of the drone's point of view: